Extenics Series

Extension Engineering

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Acknowledgment

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Authors

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Brief Introduction

The basic idea of extension engineering is to deal with contradictions in different fields with formalized methods and study how to change incompatibility into compatibility, antagonism into co-existence and the negative into positive. The book systematically elaborates the theoretical foundation, methodology and fields of application of extension engineering and presents application cases of extension engineering methods.

The characteristics of the book lie in its combination of theory with practice, thorough analysis and better operability. Each part of the book is followed by some simple and lucid cases so that readers with different backgrounds and different levels can learn something. The book is suitable for teachers and students in colleges and universities, engineers and technicians and management decision makers. It is better to be an optional course for undergraduates, post-graduates and doctoral students of related majors in colleges and universities.

Members of *Extenics Series* Editorial Board

Preface

Human history is the history of solving contradictions and making constant innovations. It is of great significance for human intelligence to analyze the possibility of extension and rules of innovation with formalized models and summarize methods of solving problems. It is of great value for improving machine intelligence to discuss theories and methods of solving contradictions by computer according to these research achievements. Extenics researches are conducted for the sake of this.

The selection of Extenics was put forward in 1976 and the first paper of “Extension Set and Incompatible Problems” was published in 1983. In the past decade, with countless painstaking efforts made by Extenics researchers, the framework of Extenics has been initially formulated; researches have been conducted in several fields and the sketch of a new discipline has been painted.

Quite a few scholars have joined in the construction of the new discipline in recent years. A number of books on Extenics are in urgent demand for the reference of researchers in order to apply, study, popularize and promote Extenics. Therefore, we have *Extenics Series* edited and it is hoped that Extenics can be introduced to scholars through the series.

It is true that currently Extenics is not completely mature yet. The research level of Extenics is to be improved; the theoretical system needs to be further constructed; application research needs to be further conducted; plenty of problems are to be addressed. As a result, the series only serves as a modest motivation for more and better achievements. Hopefully the series can provide scholars with preliminary knowledge and Extenics thinking methods as well as topics for discussion and research.

We believe that the publishing of the series will attract more scholars to join in the research of Extenics and become the new force of Extenics research so as to promote the improvement and development of Extenics. We are looking forward to your precious suggestions and your share of contribution of the construction of Extenics.

Cai Wen

Director of Extension Engineering Specialized Committee, Chinese Association for Artificial Intelligence

Expert with Special Country-level Contributions

Founder of Extenics, a New Discipline

June 26, 2002

Foreword of *Extenics Series*

"Extenics" is a new discipline established by Chinese scholars led by Professor Cai Wen. It researches the possibility of matters' extension and new rules and methods of innovation with formalized models, which are to be used to solve contradictions.

Extenics begins to take shape through many years' of hard work and joint efforts made by Extenics researchers. It includes extension theory, extension methods and extension engineering. Innovative and breakthrough achievements have been made in theory and method researches. There are many kinds of successful cases in multiple fields in actual application. Extenics and its application have attracted extensive attention from academic fields home and abroad. It has certain influences. Its main achievements are as follows:

★Extension theory includes basic-element theory, extension set theory and extension logic:

Basic-element theory puts forward the basic-elements which describe the affair, matter and relation—"matter-element", "affair-element" and "relation-element". It discusses the extensibility of basic-elements and rules of extension transformation, and studies the extension models which combine qualitative and quantitative property. It provides formalized languages that describe changes of matters and conversion of contradictions. The basic-element theory provides a new formalized tool for expression of knowledge while extension models provide models that combine qualitative and quantitative property for expression of artificial intelligence problems, which is of great importance for the development of artificial intelligence.

Extension set theory is a kind of development and breakthrough compared with traditional set theory. It is a quantitative tool which depicts the mutual transformation of matters between the positive and the negative, and the process of quantitative change and qualitative changes. Extension fields of extension set and dependent function bring hierarchy and alterability to extension set and further lay a foundation for researching contradictions and developing quantitative mathematics methods—extension mathematics and extension logic.

Extension logic is a science that studies the transformation alteration between contradictions and consistency, and rules of reasoning. It is the logic foundation of Extenics.

★Extension method is the bridge of extension theory between theory and practice. Many extension methods based on the extension theory are put forward in the process of extension research, such as divergent tree, decomposition and combination chains, correlative net, implication system and conjugate pair; superiority evaluation, true or false information judgment methods; basic transformations, compound transformations and conductive methods; rhombus thinking methods and transforming bridge methods.

★ Extension engineering applies extension methods in such fields as engineering technique, social economy, biomedicine, and traffic environment protection. Application techniques in various fields are developed while methods and techniques of various subjects and majors are combined. All this is called "extension engineering". The basic idea of extension engineering research is to deal with contradictions in different fields with formal methods and study on how to change incompatibility into compatibility, and antagonism into co-existence. In recent years, great performances have been made in application research of Extenics in fields including computers, artificial intelligence, detection, control, management and decision making. Practice has proved that the development and application of Extenics have promising prospects.

The publishing of *Extenics Series* summarizes the past years' research achievements in theory and practice of Extenics, which is of great significance for the application and popularization of Extenics. It will promote the further research and development of Extenics. Much as preliminary achievements have been made in Extenics research currently, a lot of work is to be done and there may be many kinds of difficulties and setbacks ahead. The future of science is promising although the road is not smooth. Here is a poem from me to congratulate on the publishing of *Extenics Series*:

Great space for the development of artificial intelligence,

Long way for extension engineering to go.

Chinese scholars are brave to make innovations,

Bold to attract the world's attention to the oriental.

Tu Xuyan

Honorable director-general of Chinese Association for Artificial Intelligence

Director of *Extenics Series* Editorial Board

June 1, 2002

Foreword

Extenics was founded in 1983. Over the past two decades, Extenics has initially formed its own theory framework and developed to the application field. Many scholars and professional technicians start to research and apply basic theories of Extenics to solve contradictory problems encountered in practice. The status quo of Extenics research shows that the application research and actual application stage of Extenics have approached.

The key to applying theories in actual fields rides in methods. In order to allow more scholars to address contradictions in different fields with the basic theories of Extenics, we have summarized research works in the past years, improved and developed extension methods on the basis of basic principles of Extenics. It is the bridge for extension theory to be applied in reality. Methods which combine extension methods with actual fields and solve contradictions in them are generally called extension engineering methods.

For the convenience of readers, Chapter 1 briefly introduces the overview of Extenics; Chapter 2 presents the theoretical foundation of extension engineering, extension theory; the methodology foundation of extension engineering, extension method is introduced in Chapter 3; methods of solving contradictions are discussed in Chapter 4; Chapter 5 illustrates extension engineering methods and techniques. A number of cases are given in each chapter to help readers comprehend the basic methods and possible applications of Extenics. It is expected that teaching and scientific research personnel in colleges and universities and R&D institutions can combine these methods with their own research fields to put forward extension engineering methods that are more suitable for different majors.

The book summarizes related research achievements of National Natural Science Foundation Project (70671031, 70271060, 70140003, 79870107) and Guangdong Natural Science Foundation Project (05001832, 010049) which are undertaken and participated in by the authors. The authors hope that the book can serve as a modest motivation for more and better achievements so that scholars in more fields can use extension engineering methods to deal with contradictions in their own fields; in the meanwhile we hope that the book can be a bridge to the road of Extenics application.

This book is one of the books in *Extenics Series*. The authors extend the gratitude to National Natural Science Foundation and Guangdong Natural Science Foundation for their great support! Thanks also go to Guangdong University of Technology for providing a favorable science and research environment for us, and Science Press and all members of *Extenics Series* Editorial Board for their hard work.

Negligence and even mistakes are inevitable due to the author's limitation in both ability and learning. Your kind correction will be much appreciated.

The authors

January 26, 2007

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Chapter 1 Introduction

1.1 Research Overview and Development Course of Extenics

Extenics is an original and traverse discipline put forward by Chinese scholars in 1983. It discusses the possibility of matters' extension and rules and methods of innovation with formalized models, which are used to solve contradictory problems [1-3]. Contradiction means that people's goals cannot be reached in current conditions.

Contradictory problems are ubiquitous. Is there a rule or a theory to deal with contradictory problems? It is the starting point of Extenics research to establish a set of methods and finally help people solve those contradictory problems through computers.

In the past two decades, Extenics has developed into a new discipline with a relatively mature theoretical framework from an individual's academic thinking and a piece of paper. Quite a few scholars have joined in its construction. Scholars in the country have established a secondary association—Extension Engineering Specialized Committee of Chinese Association for Artificial Intelligence. Eleven national annual meetings have been held and Science Press is having *Extenics Series* published in succession. The discipline has been applied in many fields including extension design, extension information, extension control and extension detection with artificial intelligence and computer technology, management of extension engineering and researches of traditional Chinese medicine in particular. It covers Mainland China as well as Hong Kong, Taiwan, Japan, America and Britain. In China, extension researchers in more than 20 provinces and cities such as Guangzhou, Dalian, Taiwan, Harbin, Beijing, Shanghai, Zhejiang, Wuhan and Xi'an have participated in the construction of the new discipline. With the deepening of the research, Extenics will play an active role in the national economy and social development (refer to http://web.gdut.edu.cn/~extenics/ for details).

Through many years' efforts, the research of Extenics has experienced two stages: proposal of its concept and thinking and establishment of basic theory framework. Currently it is in the stage of combination of application research and theory research. However, a lot of hard and conscientious work is needed to make Extenics a mature subject.

In February, 2004, the Identification Committee led by Wu Wenjun, academician of Chinese Academy of Science and Li Youping, academician of Chinese Academy of Engineering remarked, "through more than two decades of consecutive research, Professor Cai Wen et al has established a new discipline that covers subjects of philosophy, mathematics and engineering. It is established by our national scientists on their own and it is an original discipline of profound values" [4]. They pointed out that Extenics was of formalized, logical and mathematics characteristics.

The following consensuses were reached in the 271st academic symposium of Xiangshan Science Conferences with the theme of "scientific significance and future development of Extenics" [5] in 2005:

(1) Extenics is a newly emerging discipline with contradictory problems as its research objects, intelligent management of contradictory problems as its main research content and extension methods as the main research methods. The research of intelligent treatment of contradictory problems is of great significance for the development of modern science.

(2) "Positioning" of Extenics: Extenics is approved as an interdisciplinary subject of philosophy, mathematics

and engineering; the research objects of Extenics exist in different fields, so it is better to regard Extenics as a traverse discipline just like information theory, control theory and system theory in the discussion.

Extenics is China’s original new discipline and is gradually going abroad from China. Therefore, currently compared with the international research level of Extenics, China still takes the lead and represents the latest progress in the world. If we strengthen our research in Extenics, it is possible to obtain breakthrough technology achievements that are first-rate in the world.

Extenics is a newly emerging discipline that integrates mathematics, philosophy and engineering. Just as control theory, information theory and system theory, it is a traverse discipline that covers extensive fields. Where there is quantitative relation and space forms, there is mathematics. Likewise, where there are contradictory problems, there are chances for bringing Extenics to full play. Its application effects in various subjects and engineering fields do not lie in discovering new experiment facts but providing a kind of new thinking and method.

To solve detailed contradictory problems, we have to research formalized models that can deal with common contradictory problems and contradictory problems in different fields, operable tools that combine qualitative and quantitative property, and rules of reasoning and unique methods. As to the research of dealing with contradictory problems, just as what is pointed out by the Identification Committee mentioned above, “up to now, we haven’t seen anybody home or abroad ever have such comprehensive and deep studies”.

1.2 Theoretical Framework of Extenics

At present it has been preliminarily confirmed that the core of extension theory is basic-element theory, extension set theory and extension logic [6]. The extension theory framework with them as the pillars has been set up. The composition, basic concepts and related contents of each pillar have been initially studied. See Figure 1.1.

- Extension theory
  - Basic-element theory
    - Extensible analysis theory
      - Divergence analysis theory
      - Correlative analysis theory
      - Implication analysis theory
      - Opening-up analysis theory
    - Conjugate analysis theory
      - Imaginary and real conjugate analysis
      - Soft and hard conjugate analysis
      - Latent and apparent conjugate analysis
      - Negative and positive conjugate analysis
    - Extension tranformation theory
      - Basic extension transformations
      - Conductive transformations and conjugate transformations
      - Calculation of extension transformations
      - Nature of extension transformations
  - Extension set theory
    - Extension set
      - Basic-element extension set
      - Compound element extension set
      - Extension field and stable field
    - Depedent function
      - Definition of dependent function and calculation formula
      - Types of dependent function and its transformations
  - Extension logic
    - Extension models
    - Extension reasoning
      - Basic-element extension reasoning
      - Conductive reasoning
      - Conjugate reasoning
    - Basic-element expression and extension of propositions and reasoning sentences
    - Reasoning of solving contradictory problems

Figure 1.1 Framework of extension theory

1. Establishment of Basic-element Theory

The logical cells of Extenics are matter element, affair element and relation element (generally called basic-element) in Extenics. The basic-element concept integrates quality and quantity, action and relation into a triple which is used to describe the matter, affair and relation in a formalized way; they are used to describe millions of matters, affairs and problems as well as information, knowledge and strategy, to research the extensibility of basic-elements and rules of transformation and calculation and to establish extensible models out of mathematics models which express contradictory problems and the process of solving them. Therefore, they are formalized tools of solving contradictory problems. The extensible analysis theory of basic-elements and conjugate analysis theory of matters are studied; the types and natures of extension transformations are discussed and extension transformation theory is put forward. They are generally called basic-element theory. Up to now, the research of basic-element theory and extension models has been relatively comprehensive.

2. Establishment of Extension Set and Dependent Function

Cantor Set, classification of certain things, is the basis of mathematics for thousands of years. Fuzzy Set, put forward by Zadeh, describes fuzzy things and is the basis of fuzzy mathematics. Neutrosophic set, put forward by Smarandache in 1995, is a generalization of the fuzzy set and describes neutrosophic things—i.e. things which are based on <A>, <antiA> and <neutA>, where <A> is an attribute, <antiA> the opposite of that attribute, and <neutA> is the neutrality or reconciliation between them, and neutrosophic logic is the basis of neutrosophic mathematics. The nature of matters expressed by Cantor Set and Fuzzy Set is fixed. However changes of the nature of matters have to be taken into consideration in order to solve contradictory problems. Related matters have to possess a certain nature that it did not possess before; contradictory problems have to become consistent and compatible. The transformation between the right and the wrong cannot be described by Cantor Set and Fuzzy Set. Naturally, Cantor Set and Fuzzy Set cannot be the theory basis for solving contradictory problems. As a result, a set theory which focuses on the classification of alterability of matters is necessary.

Extension Set, which describes the changes of the nature of matters, comes into being after Cantor Set and Fuzzy Set are put forward. It integrates the ideas of contradictory transformation and conversion in dialectics into set theory. With basic-elements as its parts, Basic-element Extension Set takes both quality and quantity into consideration. Basic-element Extension Set provides theory foundation for theories and methods which address contradictory problems. Currently, preliminary researches have been made on its nature. However few researches have been made on Extension Set with basic-elements and system as its elements. What is more, research on extension relation has just begun.

We have studied dependent function, quantified calculation formula and dependent function value which represents the degree of a matter's certain nature in order to study changes of the nature of a matter in a quantitative way and illustrate quantitative changes and qualitative changes. Formula of dependent function makes people break away from excessive intervention of subjective factors and naturally people can calculate objectively according to professional knowledge and historical materials. At present, formula of low-element and low-dimensional dependent function has been set up. Their nature has been studied in details but the formula of multi-element, multi-dimensional and interval dependent function, and their nature are to be further explored.

There have been few formalized and quantified studies about contradictory problems in space form, probability and planning. Therefore, basic concepts, theories and methods of extension geometry, extension algebra and extension probability will be studied on the basis of Extension Set and dependent function in future.

3. Establishment of Extension Logic

The tools of solving contradictory problems are transformation and reasoning. Current formal logic does not take the connotations and extension of matters into consideration. Therefore, it is unable to express the transformation of matter, affair, relation and characteristics and the conductive transformation of other matters, affairs, relations and characteristics caused by the transformation. Dialectical logic has researched the changes and development of matters, discussed quantitative change and qualitative change, matters' connotations and extension. However, it is conveyed in natural language, thus, reasoning and calculation cannot be conducted and it cannot be operated by computers. As a result, we have explored a new logic—extension logic. It takes advantage of formalization of formal logic and the dialectical logic to study strengths of matters and their changes and becomes a kind of logic with the core of solving the transformation and reasoning of contradictory problems.

At present, basic concepts of extension logic have been established. A number of extension reasoning rules of basic-elements and compound elements, and reasoning forms of solving contradictory problems have been studied. However, on the whole, there is a lack of deep and systematic research works. The research of extension reasoning is still at an elementary level.

1.3 Methodology System of Extenics

So far, Extenics has researched formalized methods which describe the matter and relation, information, knowledge and problems in the real world; the possibility of matters' extension—extensibility and formalized methods of expressing it—extensible analysis methods; analysis of structure of conjugation from perspectives of materiality, dynamics, antagonism and systematicness. The extensible analysis theory and methods of basic-elements, conjugation analysis theory and methods of matters are established; the basic transformation methods of contradictory problems are put forward, including extension strategy generation methods which change incompatibility into compatibility, bridge transforming methods which deal with antagonistic problems, and crucial strategy and coordination methods which manage complicated problems on the basis of the whole.

Extenics provides a new kind of methodology for people to know, analyze and solve contradictory problems in the real world from a new perspective.

Extenics methodology [7] is generated and formalized with the guide of ideological system of Extenics. Its basic characteristics are:

(1) Characteristics of formalization and modeling: social science studies contradictory problems in natural language. In order to make people deduce strategies of solving problems according to certain programs and make computers help people generate strategies of solving contradictory problems, Extenics conveys the matter, affair, relation and problems in formalized language, establishes extension models of problems, expresses the process of qualitative change and quantitative change and critical state, and expresses the process of generating strategies and brilliant schemes so as to describe the process of solving contradictory problems. It is a model that reflects the inherent relations of research objects with symbols. It is a kind of abstract model.

(2) Characteristics of extensibility and convergence: any object is extensible in certain conditions. The extended object is again convergent. This is an important characteristic of extension methodology. It is in line with the thinking model "divergence→convergence" of human beings to solve contradictory problems. It is called a rhombus thinking model. Multi-level rhombus thinking models expresses the process of "divergence→convergence→re-divergence→re-convergence". People's innovative thinking processes include divergent thinking and convergent thinking so that it can serve as a formalized tool for studying thinking processes, especially innovative thinking processes.

(3) Characteristics of transformation and conductivity: Extenics researches matters' alterability between quality and quantity, and transformation between the negative and the positive. It researches not only direct transformations and formalizations of transformations but also the conductive function of transformations. It is the important characteristic of Extenics methodology to study the strategy generation which changes incompatibility into compatibility, transforming bridge which changes antagonism into co-existence and methods of solving conductive contradictory problems with formalized and quantitative tools.

(4) Characteristics of wholeness and comprehensiveness: Extenics conducts conjugate analysis of the wholeness of matters from four perspectives with formalized models. The research of conjugate analysis methods of knowing matters in an all-round way demonstrates China's ancient systematic views and thinking of wholeness and combines analysis methods of reductionism; the concept of basic-elements reflects the dynamic integration of quality and quantity while matters can be analyzed from a holistic view with whole-characteristic basic-elements; in extension set, the process of quantitative change and qualitative change is described with changes of dependent function values while the transformations of the universe of discourse reflect the thought of dealing with contradictory problems in a holistic perspective.

Extension methods are especially suitable for innovation, so it is also called extension innovation methods.

Figure 1.2 is the structure of extension innovation method system.

- Extension innovation methods
  - Extensible analysis methods
    - Divergence analysis method
    - Correlative analysis method
    - Implication analysis method
    - Opening-up analysis method
  - Conjugate analysis methods
    - Imaginary and conjugate analysis method
    - Soft and hard conjugate analysis method
    - Latent and apparen conjugate analysis method
    - Negative and positive conjugate analysis methods
  - Extension transformation methods
    - Basic transformation method
    - Conductive transformation method
    - Conjugate transformation method
      - Universe of discourse transformation method
      - Dependent criteria transformation method
      - Element transformation method
  - Extension set methods
    - Extension classification method
    - Extension clutering method
    - Extension identification method
    - ......
  - Superiority evaluation methods
  - Extension thinking models
    - Rhombus thinking model
    - Rerversed thinking model
    - Conjugate thinking model
    - Conductive thinking model

Figure 1.2 Structure of extension innovation methods

1. Extensible Analysis Method

Matters should be seen as extensible during the process of solving contradictory problems. Solving contradictory problems is to transform the goal or condition of problems according to the extensibility of matters so as to achieve the goal. In order to formalize the process of solving contradictory problems, we regard basic-elements as formalized tools of describing matters, affair and relation, and research extensible analysis methods which express matters' extension rules. The methodology provides people with various possible channels for solving contradictory problems. It can make people break away from the shackles of traditional fields. It is an important method that uses computers to address contradictory problems and improve machine intelligence.

2. Conjugate Analysis Method

The research of structure of matters can help us solve contradictory problems by using matters' parts and interactive relations among those parts. Matters possess characteristics of materiality, systematicness, dynamism and antagonism, which are generally called matter's conjugation. According to matters' conjugation, conducting formalized and qualitative analysis of the imaginary and real, the soft and hard, the latent and apparent, the negative and positive with matter-element and relation-element as formalized tools is called conjugate analysis method. Multi-strategies of solving contradictory problems can be obtained by analyzing conjugate parts of matters and their interactive relations and interactive transformations. Conjugate analysis method provides a new perspective for people's comprehensive analysis of matters and meanwhile it is the source of brilliant schemes of solving some contradictory problems. On the basis of holism, conjugate analysis method combines reductionism.

3. Extension Transformation Method

Transformation is a tool of transforming contradictory problems. Transformations include direct transformations and indirect transformations. Quite a few strategies of solving contradictory problems are produced by transformations of goals or conditions of related affairs, matters or relations. Therefore, in terms of methods of solving contradictory problems, we should study not only direct transformations but also indirect transformations; transformations of numbers as well as transformations of characteristics and transformations of objects themselves.

While studying transformations, we should discuss not only their forms but also subjects, methods, tools, as well as the time and place, that is, we need to study forms and connotations of transformations from qualitative and quantitative perspectives. It is necessary to study forms, connotations and effects of conductive transformations due to the correlation among research objects. We call transformations adopted in Extenics extension transformations.

Given ways of transformations, the extension transformation method includes basic extension transformation methods, transformation's calculation methods, transformation's compound methods and conductive transformation methods. Given transformation objects, the extension transformation method includes transformation methods of the universe of discourse, dependent criteria and elements of the universe of discourse, including transformations of basic-elements. If the transformation object is matter, according to matters' conjugate analysis, extension transformation method again includes transformations of conjugate parts and conductive transformations of conjugate parts.

The research of extension transformation method with the methods of establishing dependent function provides operable tools for formalizing and quantifying the process of solving contradictory problems.

4. Extension Set Method

It is necessary to set up calculation formulas that can express the qualitative change and quantitative change of matters' natures in certain transformations in order to solve contradictory problems. In Extenics, new concepts of "distance" and "side distance" which describe distance are established to break the classical mathematics rule that the distance between dots and intervals is zero. The dependent function established on the basis of this can quantitatively describe the objective reality of "differentiation among the same classification" and further describe the process of qualitative change and quantitative change.

Extension set method is to classify, recognize and gather research objects from a dynamic and transformational perspective. Extension set is a set with extension transformations and dependent function as the basis. Extension set has different extension fields and stable fields for different extension transformations so there are different forms of classification, cluster and recognition. It discloses the transformation process and transformation results of contradictory problems in a formalized and quantitative way, which makes classification, clustering and recognition dynamic and transformational and more suitable to people's thinking models and actual situation.

5. Superiority Evaluation Method

Superiority evaluation method is a practical method of evaluating an object, design and strategy by considering several measure conditions. As to the evaluation of an object, we should not only consider its advantages but also disadvantages. For example, an enterprise can gain lots of profits from a certain product but the waste gas is a great pollution to the environment. It does not gain so many profits from another product but it is non-polluted. Then which product should the enterprise produce? Both advantages and disadvantages have to be taken into consideration; comprehensive evaluation must be made in order to get a suitable choice. Besides, we have to consider dynamism and changeability as well as potential advantages and disadvantages. Superiority evaluation method has all these strengths. It calculates the suitable degree of all conditions with dependent function. The values of dependent function can be minus or plus, so the superiority can reflect the degree of advantages and disadvantages of an object, making the evaluation more practical.

6. Extension Thinking Model

Extension thinking model consists of the rhombus thinking model, reversed thinking model, conjugate thinking model and conductive thinking model. The rhombus thinking model combines extension methods and convergence methods. It is a method of solving contradictory problems that combines modeling, qualitative analysis and quantitative calculation. The reversed thinking model is a kind of thinking model which is the opposite direction of the conventional thinking model. As a kind of non-conventional innovative thinking model, its formalized research is relatively difficult and it is hard for people to grasp. However, many thinking models of reversed thinking can be given by using formalized methods of Extenics. The conjugate thinking model is a unique model of Extenics. Its basis is matters' conjugate analysis principle and conjugate transformation principle. The application of this model can make us learn the internal structure of matters more comprehensively, analyze its strengths and weaknesses and take related measure to reach expected goals according to interactive transformations of conjugate parts on certain conditions. While solving contradictory problems, we cannot directly solve them by conducting one transformation. However, conductive transformations caused by this can have problems solved. The thinking model of solving contradictory problems by conductive transformation is called the conductive thinking model.

The strength of computers is quantitative calculation. It has advantages of large storage and rapid speed. The strength of people is qualitative analysis. People are more able to deal with problems from the qualitative perspective. To solve contradictory problems, the possibility of matters' extension from the qualitative perspective has to be discussed to come up with several extension strategies; meanwhile, computers with large storage and rapid speed are necessary. Therefore the methodology of solving contradictory problems must combine quantitative calculation and qualitative analysis, formalize people's innovative thinking process, and solve contradictory problems with the help of computers, that is, realize the intelligent management of contradictory problems. Extension innovation methodology is just this kind of methodology.

Extension innovation method is an effective method of analyzing, transforming, deducing and judging contradictory problems and finally generating strategies to solve them. It formalizes the process of solving contradictory problems and provides theoretical basis and methods for people to complete the process of "discovering problems→establishing problem models→analyzing problems→generating strategies to solve problems" with formalized models. It can be realized by combining human and machines with the help of computers.

The establishment of extension innovation methodology and its preliminary application prove that through further researches, it is feasible to formalize and quantify people's innovative thinking process by using extension innovation methods and the intelligent management of contradictory problems can be realized. The further improvement of extension innovation methodology is sure to promote the development of thinking science, decision-making science and intelligent science, and it is sure to improve the scientific ability and operability of these related subject researches.

1.4 Scientific Significance of Extenics Research

Extenics has taken shape through many years of exploration. Extenics research is of the following scientific significance [8]:

1.4.1 Mathematics and Logic Foundation of Extenics Will Bring Greater Reforms to Mathematics and Logic

Mathematics usually solves compatible problems and gives up plenty of contradictory problems. Extenics researches these contradictory problems and explores rules and methods of transforming contradictory problems in formalized ways. Therefore, mathematics and logic has to be extended first and this is sure to bring greater reforms to mathematics and logic. It is mainly reflected in the following four aspects:

(1) The establishment of extension set makes static classifications in mathematics extended to transformation-based classifications in Extenics;

(2) The establishment of dependent function makes the quantitative change described in Cantor set extended to quantitative change and qualitative change described in extension set;

(3) The establishment of the basic-element concept makes mathematics model extended to extension models that combine quality and quantity;

(4) The establishment of extension logic combines formal logic and dialectical logic to deal with logic relations of the process of addressing contradictory problems.

The four extensive extensions of extension theory in terms of mathematics and logic, so greater reforms in mathematics and logic are brought about, thus extension mathematics is formed. Its differences and relations with classical mathematics and fuzzy mathematics are as follows:

Table 1.1 Differences and relations between extension mathematics and classical mathematics and fuzzy mathematics

Formal models	Set foundation	Nature function	Value range	Distance concept	Logic thinking	Problems
Mathematics model	Cantor set	Characteristic function	{0,1}	Distance	Formal logic	Determined problems
Fuzzy mathematics model	Fuzzy set	Subordinate function	[0,1]	Distance	Fuzzy logic	Fuzzy problems
Extension model	Extension set	Dependent function	$(-\infty,+\infty)$	Distance, Side distance	Extension logic	Contradictory problems

1.4.2 Extenics Builds the Bridge between Natural Science and Social Science

1. Extension Models and its Philosophical Foundation of Solving Contradictory problems

Any science discovery naturally entails summarized views of the objective world which are outlooks on nature when they are expressed in the way of philosophy. The change of the past summarized views leads to new science theory and finally a new thinking mode is formed. Extenics includes the basic thought of extension transformation in the general principle framework of science thinking. Extenics does not admit absolute concept of either black or white nor does it admit absolute both black and white. Instead it treats the black and white as something changeable and investigates their interactive transformations. The concept of transformation is the fundamental philosophical concept of Extenics. It develops the past summarized concept of "transformation" of outlook on nature. It provides the dialectical and right thinking mode for Extenics and outlook on nature foundation for formalization and logicalization of innovative thinking. It demonstrates the close relations between outlook on nature of dialectical materialism and extension theory. Meanwhile Extenics provides basic methods of looking for transformation terms. It studies the transformation between the transformed terms and the transformation terms with formalized models. The model is an extension model. The basis of using extension models to solve contradictory problems is the extensible analysis theory of basic-elements and matters' conjugate analysis theory.

The outlook on nature which is relied on by the new discipline in development is not necessarily something available in the current philosophy system. Otherwise there is no progress of philosophy and science. The research objects of Extenics are contradictory problems in the real world which are barriers to people's transforming the world. Solving contradictory problems is the ladder for human beings' advance. The background of Extenics for solving contradictory problems—the general image of the objective world is the basis of Extenics for solving contradictory problems. In Extenics, the objective world is a world of basic-elements. To solve contradictory problems of the objective world is to solve contradictory problems among basic-elements. The core concept of basic-element theory is the extensibility of basic-elements and matters' conjugation. This is the theoretical cornerstone of solving contradictory problems.

What basic-element theory unfolds for us is a picture of the objective world: the real world is a matter-element set or matter-element system. Their interactive functions constitute an affair-element set or an affair-element system; their interactive influences form a relation-element system. The interactive link and functions among basic-elements transforms each other on certain conditions; the forms and results of transformations can be realized through proper extension transformations. The picture has laid a foundation for a kind of formalized system of knowing the world and transforming the world.

2. Exploring the Bridge Connecting Natural Science and Social Science

Marx pointed out, “Natural science will in future summarize the science about human beings as its branch just as the science about human beings will summarize natural science as its branch. It is going to be a science.”

(1) Extension model explores the road from social science to natural science

If a certain social science is only confined to natural language, it is not a true science. Only when the whole or part of it is described quantitatively by mathematics can it be in the field of science.

Extension theory sets up extension models that describe the matters, affairs, relations and problems of the objective world, and formalized models that express unity of opposites, rules of qualitative change and quantitative change, and negation of negation. Calculable formulas are formulated. Therefore, it bridges the gap between natural science and social science and explores the road from social science to natural science.

(2) Extension method explores the door of natural science to social science

Extension transformations of changing incompatibility into compatibility in natural science and engineering have to follow the basic rule of natural dialectic. Extension methods express related rules and methods of social science with formalized models. Achievements are made when social science is used by natural science. The door to social science is open. In future through the door communication between natural science and social science will be gradually made.

(3) Extenics will be gradually developed into a bridge that links natural science and social science

With the deepening of Extenics research, scholars of social science join in Extenics research. They can take advantage of the open door and the travelled path to gradually expand communication channels and have more achievements of social science expressed with extension models; these formalized rules and methods will gradually enter natural science and be applied in the research of natural science.

In short, Extenics represents human beings’ advanced thinking model. It tries to be in line with the dialectical outlook on nature while formalizing a dialectical outlook on nature. There are two basic things in terms of its function: for natural science it introduces the most dialectical thing of thinking model in it and makes natural science more rational; for social science it formalizes and qualifies the qualitative dialectical transformation concepts, and makes it a science with a formalized and quantitative description. Therefore the bridge that connects natural science and social science is built. The bridge will be further improved, shaped and consolidated with the development of Extenics.

1.4.3 Build Methodology of Solving Contradictory problems

Extenics establishes the methodology of solving contradictory problems and discusses people’s innovative thinking process in a formal, mathematical and logical way so as to conduct intelligent management of contradictory problems. The further improvement of extension methodology is sure to promote the development of thinking science, decision-making science and intelligent science, and improve the operability of these related subjects. Its methodological significances are:

1. Systematically Combine the Researches of Quality and Quantity, and Describe Qualitative Change and Quantitative Change in a Formalized Way

All matters in the objective world are the integration of quality and quantity. They are closely related and constrained with each other. However, what mathematics does is to abstract quantity and forms of objects and abandon matters' nature. It is extensively adaptable, but the resolution of plenty of contradictory problems needs the transformation of quantity and transformation of quality; mathematics can do nothing. The establishment of matter-element breaks the framework of mathematics and reflects the dialectical relation between quality and quantity.

The concepts of nature and degree function and joint field in Extenics indicate the dialectical rules from quantitative change to qualitative change. The concept of joint field expresses the variation range of quantity stipulated by matters' nature. When the transformation of quantity is conducted in the joint field, the quality is stable; when the transformation of quantity goes beyond the joint field, it leads to the transformation of quality. The corresponding things are the stability field and extension field of extension set.

It is the important function of Extenics to describe qualitative change and quantitative change in formalized language. This provides formalized models for human beings' related intelligent activities.

2. Introduce Extension Transformation and its Calculation as the Basic Tools of Solving Contradictory Problems

Extension transformation is the basic tool of Extenics. Its characteristics that are different from that of mathematics are as below:

The key to a strategy generation method of solving contradictory problems is the extension transformation that changes incompatibility into compatibility that is resolution transformation. Extension transformation breaks the framework of mathematics transformation and its dense nature of experimental science and engineering science.

In Extenics, conductive transformation is a very important tool. It conveys the influences of elements transformation over related matters and affairs. Meanwhile, the impact of transformations on the wholeness is demonstrated by conductive effects.

3. Make People Break Away from Traditional Fields with Extensible Analysis Method

Matters' extensibility is put forward in Extenics and an extensible analysis method is studied. People get rid of control of traditional fields and can deduce many possible plans of solving contradictory problems by using extension transformations and extension reasoning.

On the other hand, the multi-plans of solving contradictory problems can be converged by evaluating method. Better strategies of solving contradictory problems are obtained through several times' extension and convergence. This kind of rhombus thinking method becomes the formalized tool of expressing innovative thinking.

4. Analyze Matters' Structure and Relation between Internal and External from the Conjugation Perspective

Extenics analyzes matters' structure and internal and external relation from the four perspectives of materiality, systematicness, dynamism and antagonism with formalized models. It is called conjugation which is the extension of systematicness. It makes people learn about the matters' structure and external and internal relation in a more comprehensive way. Therefore it provides the basis for generating strategies of solving contradictory problems especially brilliant schemes.

5. Study the Method which Combines the Holistic View and Reductionism

Extenics analyzes matter, affair and relation with basic-element theory and studies their different characteristics and the extended basic-elements; on the other hand, whole-characteristic basic-element and conjugation matter-element studies matter, affair and relation in a holistic view.

Extenics uses conductive transformation studies strategies to solve problems from the holistic, external and internal perspectives. On the other hand, Extenics discusses transformations of universe of discourse and dependent criteria from the perspective of extension set. It explores theories and methods of solving contradictory problems from both holistic and partial perspectives.

The holistic transformations, transformations of holistic key points and environment in Extenics study contradictory problems from a holistic perspective view. The method of combining holistic view and reductionism brings about better plans and key strategies of solving complicated problems.

1.5 Research Overview of Extension Engineering

Extension theory and extension methods cross and integrate with many fields, thus comes extension engineering [9-10].

Extenics researchers integrate extension theory and extension methods with many fields, put forward extension engineering theory and methods of these fields. Currently preliminary achievements have been made. If we strengthen our research, it is possible to obtain research achievements that are unprecedented in the world.

Where there are contradictory problems, there are chances for bringing Extenics into full play. The combination of basic theories of Extenics and knowledge of different fields expands the theories of those fields and generates extension engineering methods of solving those fields' contradictory problems. Currently those fields include:

1. Integration with Information Science

Extenics has studied the application of extension models in information fields. It represents information with matter-element, affair-element and relation element, establishes formalized models of information and knowledge, and generates strategies of solving contradictory problems through extension transformations and extension reasoning.

Varied contradictory problems exist on the internet, especially complicated networks, such as unbalanced demands and supplies of information, and contradictory problems in the big world and small world. Content processing has become the bottleneck of computer applications such as browsing, retrieval, integration and gridding. New tools need to be explored in order to solve these contradictory problems. It is feasible to solve contradictory problems on the internet with Extenics. Complicated problems can be simplified by establishing extension models and generating strategies with extension reasoning, extension transformation, conductive transformation, and conductive effects.

The process of many intelligent activities even all intelligent activities can be treated or abstracted as the process of “solving problems”. The contradictory problems studied by Extenics are the difficult points and solving contradictory problems is an important intelligent activity. It is also the reflection of an artificial intelligence level. It is more innovative than common resolutions. The intelligence is emphasized. The further research of solving contradictory problems is helpful to the improvement of the artificial intelligence level.

Strategy generation theory and methods of solving contradictory problems are an important aspect for the combination of Extenics and information science. This will be the foundation for studying computers with high intelligence and intelligent machines that deal with contradictory problems. Extenics researchers at Guangdong University of Technology and National University of Defense Technology have discussed the extension model of “formalized system of information—knowledge—strategy” and transformations of generation strategy, studied the basic concepts and ideas of extension strategy generation methods and extension data mining methods that mine transformations and undertaken corresponding National Natural Science Foundation Project and Guangdong National Natural Science Foundation Project. *Extension Strategy Generation System* [11] summarizes the research works and the basic thinking and ways of implementing extension methods on computers. Currently Extenics researchers of a dozen of domestic universities are actively studying computer software for extension methods. The extension strategy generation system that is being studied is the realization of the technology. Extension data mining theory and method on the basis of mining “changeable knowledge” will provide transformation sources for generating strategies of solving contradictory problems.

We have to study logic with contradiction presupposes in order to make computers solve contradictory problems with extension models and generate strategies. Extension logic researches the reasoning rule of contradiction transformation and provides theoretical basis for improving intelligence levels for artificial intelligence fields.

The extensibility in extension theory is of important value for theory and methods of artificial intelligence. It will be the basis of dealing with problems with artificial intelligence and generating strategies. It can be expected that Extenics will become a theoretical foundation for artificial intelligence.

2. Integration with Engineering Science

Plenty of contradictory problems exist in control and detection fields such as antagonism of accuracy, stability and rapidness in control, contradiction of detection parameters and incompetence of detecting instruments in detection, requirement of detecting instruments and detecting environment. The problems of being unable to control and detect affect the level of automation.

On the other hand, when machines are in operation, varied contradictory problems usually happen. Can we install an intelligent system in the machine to solve those contradictory problems? When contradictory problems happen in the machine, the system can generate strategies and order the machine to transform them into non-contradictory ones. This is an important task with foresight. Its purpose is to create a high-level intelligent system.

To achieve this, we have to combine basic theories and methods of Extenics with professional knowledge of control fields and detection fields in order to obtain extension engineering theory and methods of solving contradictory problems in the field.

To solve the contradictory problems of being uncontrollable and controllable of the control system, Professor Wang Xingyu of East China University of Science and Technology put forth the concept, definition and framework of extension control. In recent years some scholars in Taiwan and Mainland China have kept exploring the application of extension control. However, systematic theory and methodology has not been formed in extension detection and extension control. At present, extension control theory and method and extension detection theory and method are two branches that attract the most numerous studies. It will be expanded to other fields in future. Professor Yu Yongquan of Guangdong University of Technology has studied new methods and technology for solving contradictory problems in the detection field according to some physical quantities in the control system that cannot be detected or is hard to be detected. He put forward the basic concept, thinking and some natures of extension detection and undertakes corresponding National Natural Science Foundation Project and Guangdong National Natural Science Foundation Project. He has published several papers about it.

Professor Zhao Yanwei of Zhejiang University of Technology establishes the model of concept design and preliminary application methods in her undertaken National Natural Science Foundation Project according to plenty of contradictory problems in design field. Professor Zou Guangtian of Harbin Institute of Technology combines extension theory, architecture and computer for study, comes up with "extension architecture planning and design" which deals with contradictory problems in architecture design and undertakes the corresponding National Natural Science Foundation Project. Professor Yang Guowei of Qingdao University studies products' concept design and recognition of extension models with extension methods and undertakes the corresponding National Natural Science Foundation Project and has obtained many research achievements.

3. Integration with Management Science

Management extension engineering examines the process of management from the perspective of solving contradictory problems. With Extenics, a new set of management engineering theory and method will be established, including extension planning, extension marketing and extension decision-making. The maturity of management extension engineering theory and method will make extension theory and management science closer to each other.

In the past decade, with the great support of management science department of National Natural Science Foundation, Extenics scholars of Guangdong University of Technology, Zhejiang University and Nanjing University of Finance and Economy have undertaken several National Natural Science Foundation projects, researched rules of solving management contradictory problems and had a number of preliminary achievements in extension thinking, extension marketing, extension planning, extension decision making, key strategy and transforming bridge theory published. They have also discussed the basic concept and thinking of management extension engineering. However, these researches are relatively shallow and scattered. It is necessary to conduct systematic researches of management extension engineering theory and method so as to form the basic theory and methodology of management extension engineering.

4. Integration with Other Subjects

The further research of Extenics is sure to result in the research of innovative thinking by computers. The research will be the integration of thinking science, computer science and extension theory. The established theory and method will promote the research and production of intelligent machines which imitate the innovative thinking of human brains and which are the extension of human brains.

Extenics researchers of Guangzhou University of Chinese Medicine and Ji'nan University study contradictory problems existing in traditional Chinese medicine with extension theory with the help of National Natural Science Foundation in order to discuss the application of extension method in the field of traditional Chinese medicine. However, those studies are preliminary. It is necessary to establish traditional Chinese medicine extension diagnosis methodology with a combination of extension methods and clinical epidemiology. It is a science that involves many subjects and a newly emerging interdisciplinary science with a wide range of applications no matter whether it is considered from the perspective of research objects of Extenics or analyzed from the perspective of the past and future of Extenics. It will be integrated with more and more sciences in future development.

Chapter 2 Theoretical Basis of Extension Engineering – Extension Theory

The theoretical basis of extension engineering is extension theory, including three pillars of basic-element theory, extension set theory and extension logic. For easy study and application by the readers, this chapter firstly introduces the contents related to extension theory, including the concept of basic-element, principle of extensible analysis, principle of conjugate analysis, extension transformation, compound-element, extension set, dependent function, extension logic, and other rudimentary knowledge.

2.1 Concept of Basic-Element

For formalized description of matter, affair and relation, the concepts of matter-element, affair-element and relation-element are established as the logic cells of Extenics, collectively referred to as basic-element. The concepts of matter-element, affair-element, relation-element and basic-element are respectively introduced in the following parts, with a brief introduction of the logical operation of basic-element.

2.1.1 Matter-Element

Definition 2.1 an ordered triple composed of the measure v_m of O_m about c_m, with matter O_m as object, and c_m as characteristic

$$M=(O_m, c_m, v_m)$$

As the fundamental element for matter description, it's referred to as 1-dimensional matter-element, and O_m, c_m, v_m are referred to as the three key elements of matter-element M, within which, the two-tuples composed of c_m and v_m (c_m, v_m) is referred to as the characteristic-element of matter O_m.

For convenience, the whole matter-element is expressed as £ (M), the whole matter is expressed as £ (O_m), and whole characteristic as £ (c_m). The domain of measure of characteristic c_m is expressed as V (c_m), referred to as the domain of measure of c_m.

A matter with multiple characteristics, similar to 1-dimensional matter-element, can be defined as a multi-dimensional matter-element:

Definition 2.2 the array composed of matter O_m, n-names of characteristics of c_{m1}, c_{m2}, … , c_{mn} and the corresponding measure v_{mi} (i=1,2, …, n) of O_m about c_{mi} (i=1,2, …, n)

$$M=\begin{bmatrix} O_m, & c_{m1}, & v_{m1} \\ & c_{m2}, & v_{m2} \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn} \end{bmatrix}=(O_m, C_m, V_m)$$

is referred to as n-dimensional matter-element, wherein

$$C_m=\begin{bmatrix} c_{m1} \\ c_{m2} \\ \vdots \\ c_{mn} \end{bmatrix}, \quad V_m=\begin{bmatrix} v_{m1} \\ v_{m2} \\ \vdots \\ v_{mn} \end{bmatrix}.$$

For example,

$$M_1 = \begin{bmatrix} \text{person}A, & \text{height}, & 170\text{cm} \\ & \text{weight}, & 60\text{kg} \end{bmatrix}$$

$$M_2 = \begin{bmatrix} \text{table } B, & \text{length}, & 100\text{cm} \\ & \text{width}, & 60\text{cm} \\ & \text{weight}, & 15\text{kg} \end{bmatrix}.$$

Matter changes with time t, and can be described by matter-element

$$M(t)=(O_m(t),\quad c_m,\quad v_m(t))$$

Similarly, matter changes with the change of spatial location and other conditions. Therefore, parametric matter-element is specified.

Definition 2. 3 in matter-element $M=(O_m, c_m, v_m)$, if O_m and v_m are functions of parameter t, M is referred to as parametric matter-element, expressed as

$$M(t)=(O_m(t), c_m, v_m(t)).$$

Now, $v_m(t)=c_m(O_m(t))$. For convenient writing, at place without causing confusion, parameter t is disregarded, and briefly expressed as

$v_m=c_m(O_m)$, which describes the relation between matter and its measure about certain characteristic.

Multiple characteristics has multi-dimensional parametric matter-element, and expressed as

$$M(t) = \begin{bmatrix} O_m(t), & c_{m1}, & v_{m1}(t) \\ & c_{m2}, & v_{m2}(t) \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn}(t) \end{bmatrix} = (O_m(t),\ C_m,\ V_m(t))$$

As to a given matter, it has corresponding measure value about any characteristic, which is unique at any moment. When this measure does not exist, it's expressed as empty measure Ø. If the measure of matter O_m about characteristic c_m is not empty, c_m is referred to as non-empty characteristic of O_m.

Definition 2.４ the matter-element corresponding to all non-empty characteristics of matter O_m

$$\begin{bmatrix} O_m, & c_{m1}, & v_{m1} \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn} \\ & \vdots & \vdots \end{bmatrix}$$

is referred to as the all characteristics matter element of matter O_m, expressed as cp$M(O_m)$.

At a determined moment, all characteristics matter-element of matter O_m is unique. For any two different matters O_{m1} and O_{m2}, at least one characteristic c_m can be found to make $c_m(O_{m1})\neq c_m(O_{m2})$.

As to two matter-elements $M_1=(O_{m1}, c_{m1}, v_{m1})$, $M_2=(O_{m2}, c_{m2}, v_{m2})$, if and only if $O_{m1}=O_{m2}, c_{m1}=c_{m2}, v_{m1}=v_{m2}$, it's considered M_1 is equal to M_2, denoted as $M_1 = M_2$.

2.1.2 Affair-Element

Interaction between matters is referred to as affair, described by affair-element.

Definition 2.5 the ordered triple composed of action O_a, action's characteristic c_a and the obtained measure v_a of O_a about c_a

$$A=(O_a, c_a, v_a)$$

is used as the fundamental element for affair description, referred to as 1-dimensional affair-element.

Basic characteristics of action include dominating object, acting object, receiving object, time, location, degree, mode, and tool, etc.

Definition 2.6 the array composed of action O_a, n-characteristics c_{a1}, c_{a2},…, c_{an} and the obtained measure v_{a1}, v_{a2},…, v_{an} of O_a about c_{a1}, c_{a2},…, c_{an}

$$\begin{bmatrix} O_a, & c_{a1}, & v_{a1} \\ & c_{a2}, & v_{a2} \\ & \vdots & \vdots \\ & c_{an}, & v_{an} \end{bmatrix} = (O_a, C_a, V_a) \stackrel{\Delta}{=} A$$

is referred to as n-dimensional affair-element, wherein

$$C_a = \begin{bmatrix} c_{a1} \\ c_{a2} \\ \vdots \\ c_{an} \end{bmatrix}, \quad V_a = \begin{bmatrix} v_{a1} \\ v_{a2} \\ \vdots \\ v_{an} \end{bmatrix}.$$

Definition 2.7 in A= (O_a, c_a, v_a), if O_a and v_a are functions of certain parameter t, A is referred to as parametric affair-element, expressed as

$$A(t)=(O_a(t), c_a, v_a(t)).$$

For multi-dimensional affair-element, it's expressed as

$$A(t)=(O_a(t), C_a, V_a(t)).$$

When t indicates time, the affair-element $A(t)$ is referred to as time sequence affair-element; when t indicates location, the affair-element $A(t)$ is referred to as spatial sequence affair-element.

As to the given affair-elements $A_1 = (O_{a1}, c_{a1}, v_{a1})$ and $A_2 = (O_{a2}, c_{a2}, v_{a2})$, it's considered A_1 is equal to A_2, and if and only if $O_{a1} = O_{a2}$, $c_{a1} = c_{a2}$, $v_{a1} = v_{a2}$, it's denoted as $A_1 = A_2$.

2.1.3 Relation-Element

In the boundless universe, there is a network of relations among any matter, affair, person, information, knowledge and other matter, affair, person, information and knowledge. Because of interaction and interplay among these relations, the matter-element, affair-element and relation-element describing them also have various relations with other matter-elements, affair-elements and relation-elements, and the changes of these relations will also be interacting and interplaying. Relation-element is a formalized tool to describe this kind of phenomena.

Definition 2.8 the n-dimensional array (of relation-element) composed of relative or relation symbol (referred to as relation name) O_r、 n-characteristics c_{r1}, c_{r2}, … , c_{rn} and corresponding measure v_{r1}, v_{r2}, …, v_{rn}

$$\begin{bmatrix} O_r, c_{r1}, v_{r1} \\ \quad c_{r2}, v_{r2} \\ \quad \vdots, \quad \vdots \\ \quad c_{rn}, v_{rn} \end{bmatrix} = (O_r,\ C_r,\ V_r) \overset{\Delta}{=} R$$

to describe the relation between v_{r1} and v_{r2}, is referred to as n-dimensional relation-element, wherein

$$C_r = \begin{bmatrix} c_{r1} \\ c_{r2} \\ \vdots \\ c_{rn} \end{bmatrix}, \quad V_r = \begin{bmatrix} v_{r1} \\ v_{r2} \\ \vdots \\ v_{rn} \end{bmatrix}.$$

For convenience, the above relation-element is usually denoted as $R(O_r, v_{r1}, v_{r2}, \cdots)$.

For example,

$$R_1 = \begin{bmatrix} \text{paternity,} & \text{antecedent,} & v_{r1} \\ & \text{consequent,} & v_{r2} \\ & \text{degree,} & 100 \\ & \text{maintaining mode,} & \text{kin} \\ & \vdots & \vdots \end{bmatrix} = \begin{bmatrix} O_r, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & c_{r3}, & v_{r3} \\ & c_{r4}, & v_{r4} \\ & \vdots & \vdots \end{bmatrix}$$

which describes the paternity between person v_{r1} and person v_{r2}.

While

$$R_2 = \begin{bmatrix} \text{friendship} & \text{antecedent,} & A \\ & \text{consequent,} & B \\ & \text{degree,} & \text{close} \\ & \text{maintaining mode,} & \text{emotion} \\ & \text{contact channel,} & \text{direct meeting} \\ & \text{contact method,} & \text{conversation} \\ & \text{location,} & \text{location } D \end{bmatrix}$$

describes the friendship between A and B.

Among the above characteristics, c_{r1}, c_{r2}, c_{r3} are the basic characteristics commonly used to express the objects and the degree of the relation.

Definition 2.9 In the relation-element *R*, if the relation described by *R* is function of certain parameter, it's denoted as

$$R(t)=\begin{bmatrix} O_r(t), & c_{r1}, & v_{r1}(t) \\ & c_{r2}, & v_{r2}(t) \\ & \vdots & \vdots \\ & c_{rn}, & v_{rn}(t) \\ & \vdots & \vdots \end{bmatrix}$$

This is a parametric relation-element that describes the change of relation O_r between v_{r1} and v_{r2} with the change of parameter *t*, and when *t* is a time parameter, $R(t)$ describes the dynamic change of relation O_r between v_{r1} and v_{r2} with the change of time *t* (including the change of relation degree). The influence of different persons, affairs and matters can also cause changes of relations that are reflected in the changes of relation degrees. If the relation degree between v_{r1} and v_{r2} is denoted as $v_{r3}(v_{r1}, v_{r2})$, then

$$v_{r3}(v_{r1}, v_{r2})=f(t, O_m, M, A, R')$$

wherein, *t* may be time, space or other parameter, O_m is person or matter, *M* is matter-element, *A* is affair-element, and R' is other relation-element.

The change of relation degree expresses establishment, deepening, interruption or worsening of the relation, which may be positive value, zero, or negative value.

As to the two relation-elements

$$R_1=\begin{bmatrix} O_{r1}, & c_{r1}, & v_{r11} \\ & c_{r2}, & v_{r12} \\ & \vdots & \vdots \\ & c_{rn}, & v_{r1n} \end{bmatrix},\ R_2=\begin{bmatrix} O_{r2}, & c_{r1}, & v_{r21} \\ & c_{r2}, & v_{r22} \\ & \vdots & \vdots \\ & c_{rn}, & v_{r2n} \end{bmatrix}$$

If and only if $O_{r1}= O_{r2}$, and $v_{r1i}= v_{r2i}$ is available to all $i\in\{1,2,\ldots,n\}$, it's considered the two relation-elements are equal, donated as $R_1 = R_2$.

When solving contradictory problems, we have to face numerous and complicated relations among persons, affairs and matters. One basic task for decision makers is to sort out the relations among persons, affairs, matters, between person and affair, person and matter, and between affair and matter, by which to conduct creative thinking, to realize mutual coordination and promotion among these key elements, to achieve the goal. Therefore, how to recognize these relations appears particularly important, because essentially mastering these relations requires a hard exploring process of separating the chaff from the wheat, discarding the false and retaining the true, and from the outside to the inside.

2.1.4 Basic-Element

Matter-element, affair-element and relation-element are collectively referred to as basic-element. In the situation without causing confusion, basic-element is expressed as

$$B = (O,\ C,\ V) = \begin{bmatrix} Object, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

wherein, O (Object) indicates certain objects (matter, action or relation), c_1, c_2,…, c_n indicate n-characteristics of the object O, v_1, v_2,…, v_n indicates the corresponding measure of object O about the above characteristics, and

$$C = \begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{bmatrix},\quad V = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$$

For one class of objects, we specified the concept of class basic-element:

The given class of objectives $\{O\}$, if $v_i = c_i(O) \in V_i$ for any one $O \in \{O\}$ about characteristic $c_i (i = 1, 2, \cdots, n)$, is referred to as set of basic-elements

$$\{B\} = \begin{bmatrix} \{O\}, & c_1, & V_1 \\ & c_2, & V_2 \\ & \vdots & \vdots \\ & c_n, & V_n \end{bmatrix} = \left(\{O\},\quad C,\quad V\right)$$

This is a class basic-element, wherein V_i is the domain of value-measure of class object $\{O\}$ about characteristic c_i. For convenience, class basic-element is usually expressed as B.

It's obvious that class basic-element includes class matter-element, class affair-element and class relation-element.

For example, to describe the situation of employees in certain organization, it can be expressed by class matter-element as:

$$\{M\} = \begin{bmatrix} \{\text{employee}\}, & \text{age } c_1, & V_1 \\ & \text{gender } c_2, & V_2 \\ & \text{education } c_3 & V_3 \\ & \text{professional title } c_4, & V_4 \\ & \text{post } c_5, & V_5 \end{bmatrix}$$

Class affair-element

$$\{A\}=\begin{bmatrix} \{\text{sing}\}, & \text{dominating object } c_1, & V_1 \\ & \text{acting object } c_2, & V_2 \\ & \text{time } c_3 & V_3 \\ & \text{location } c_4, & V_4 \\ & \text{degree } c_5, & V_5 \end{bmatrix}$$

can indicate "what to sing", "who sing(s)", "when to sing", "where to sing" and "degree of singing", etc.

2.1.5 Logical Operation of Basic-Element

Given basic-element B_1=(O_1, c_1, v_1), B_2=(O_2, c_2, v_2).

(1) "AND operation" of B_1 and B_2 refers to obtaining B_1 and then obtaining B_2, denoted as $B=B_1\wedge B_2$.

(2) "OR operation' of B_1 and B_2 refers to obtaining at least one of B_1 and B_2, denoted as $B=B_1\vee B_2$.

It's obvious, $B_1\wedge B_2= B_2\wedge B_1$ and $B_1\vee B_2= B_2\vee B_1$.

(3) Basic-element $B=(O, c, v(t))$, $v(t)\in V_0$ is denoted as $B=(O, c, V_0)$. When $B_1=(O, c, u)$ and $u\notin V_0$, it's considered B_1 is the non-basic-element of B, denoted as $\overline{B}=B_1$. When $V_0=\{v_0\}$, $\overline{B}=(O, c, u)$, $u\neq v_0$, the operation changing basic-element B to $\overline{B}$ is referred to as NOT operation of basic-element, denoted as $\neg B$. It's obvious

$$\neg B=\{\overline{B} \mid \overline{B}=(O, c, u), u\notin V_0\}=\{\overline{B}\}.$$

For example, if M= (pupil, age of 6—12), then

$$\{\overline{M}\}=\{(\text{pupil, age}, u), u\leq 6, \text{ or } u\geq 12\}.$$

For another example, if A= (sing, dominating object, song), song $\in${anti-Japanese military song},

$\neg A$ = {(sing, dominating object, u), $u \notin$ {anti-Japanese military song}}

Then (sing, dominating object, Huangmei opera) $\in\neg A$, (sing, dominating object, Protect the Yellow River) $\notin\neg A$.

2. 2 Principle of Extensible Analysis

The principles of extensible analysis of basic-elements include the principles of divergent analysis, correlative analysis, implication analysis and opening-up analysis.

2.2.1 Principle of Divergent Analysis

Principle 2. 1 From one basic-element, multiple basic-elements with the same object can be extended, and the set of basic-elements with the same object must not be an empty set, i.e.

$$B=(O,\ c,\ v)-|\{(O,\ c_1,\ v_1),\ (O,\ c_2,\ v_2)\ \cdots,\ (O,\ c_n,\ v_n)\}$$
$$=\{(O,\ c_i,\ v_i), i=1,2,\cdots,n\}$$

This principle is obtained from the divergence of "one object and multiple characteristics". According to the definition of multi-dimensional basic-element, the above equation can also be written as

$$B=(O,\quad c,\quad v)-|\begin{bmatrix} O, & c, & v \\ & c_1, & v_1 \\ & \cdots & \cdots \\ & c_n, & v_n \end{bmatrix}$$

According to Principle 2.1, when solving contradictory problem, if the contradictory problem cannot be solved by using one certain basic-element, it can be considered to solve the problem by using the basic-element formed by other characteristics and the object of the basic-element.

[Example 2. 1] As to a sheet of paper A, we know it's writable, i.e. the matter-element

$$M=(\text{paper}\,A,\quad \text{writable},\quad v_m)=(O_m,\quad c_m,\quad v_m)$$

When we need to "write", we can use paper A, but if we need to "pack an object", only considering the characteristic c cannot solve our problem. Hence, we can consider the matter-element of the same matter M

$$M_1=(\text{paper}\,A,\quad \text{foldability},\quad v_{m1})=(O_m,\quad c_{m1},\quad v_{m1})$$

Now whether this matter can solve our problem depends on the evaluation of v_{m1}. If the value v_{m1} is very small, i.e. paper A is hardboard, then M_1 cannot solve the problem. Here we have to consider other matters. If our desk is shaky, and a matter is needed to be laid under the desk leg, from matter-element M, we can not only extend M_1, but also extend

$$M_2=(\text{paper}\,A,\quad \text{thickness},\quad v_{m2})=(O_m,\quad c_{m2},\quad v_{m2})$$

i.e.

$$M-|\begin{cases} M_1=(O_m,\quad c_{m1},\quad v_{m1}) \\ M_2=(O_m,\quad c_{m2},\quad v_{m2}) \end{cases}$$

If the value v_{m1} is big, i.e. excellent foldability, the paper A can be folded to be laid under the desk leg to solve the problem; if the value v_{m1} is very small, i.e. poor foldability, now the value v_{m2} is generally bigger, then M_2 can be directly used to solve the problem.

Principle 2.1 provides multiple approaches to solve problems. But when considering the characteristics in basic-element, it should be noted not to artificially add improper limit to the object, otherwise not only will the problem not be solved, but the soluble problem will become insoluble. Such as the popular game of using matches to arrange patterns: it's required to arrange four square by 6 matches, which is a soluble problem, but many people think it's a contradiction, mainly because they conducted improver extension of the matter as follows:

$$M = (\text{triangles set A}, \quad \text{number of triangles}, \quad 4) \dashv \begin{cases} M_1 = (\text{triangles set } A, \quad \text{location}, \quad \text{plane}) \\ M_2 = (\text{triangles set } A, \quad \text{triangle side length}, \quad a) \end{cases}$$

(wherein, a is the length of each match) i.e. matters M_1 and M_2 cannot help solve the problem, but become obstacles for problem solving because of improper evaluation of their measures.

Inference 2.1 From one basic-element, multiple basic-elements with the same object and value can be extended, i.e.

$$B = (O, \quad c, \quad v) \dashv \{(O, \quad c_1, \quad v), \ (O, \quad c_2, \quad v) \ \cdots, \ (O, \quad c_n, \quad v)\}$$

The set of basic-elements extended by inference 2.1 is referred to as a set of basic-elements with the same object and value.

In terms of affair-element, this principle is obtained by the divergence of "one action and multiple characteristics" of affair.

[Example 2. 2] An enterprise plans to prepare a plan to "improve market share" pertinent to the situation of the enterprise's product sales in City D. But how to reify the objective is the key to communication between the planner and decision maker.

The following is a formalized method to reify the objective by using Principle 2.1.

The formalized expression of the affair "to improve market share" by affair-element is:

$$A = (\text{improve, dominating objective, market share}) = (O_a, \quad c_a, \quad v_a)$$

According to principle 2.1, action O_a has not only the characteristic c_a, but also the characteristics of the acting object, receiving object, quantity, time, location, mode and degree, etc. i.e. A can be extended to

$$A \dashv \begin{cases} A_1 = \text{(improve, acting object, enterprise E)} \\ A_2 = \text{(improve, receiving object, product P)} \\ A_3 = \text{(improve, location, City D)} \\ A_4 = \text{(improve, degree, 10\%)} \end{cases}$$

It's also indicated by this principle that a 1-dimensional affair-element can be extended to a multi-dimensional affair-element, i.e.

$$A = (O_a, \quad c_a, \quad v_a) \dashv \begin{bmatrix} O_a, & c_a, & v_a \\ & c_{a1}, & v_{a1} \\ & \cdots & \cdots \\ & c_{an}, & v_{an} \end{bmatrix}$$

The above example can also be written as

$$A -| A' = \begin{bmatrix} \text{improve,} & \text{dominating object,} & \text{market share} \\ & \text{acting object,} & \text{enterprise E} \\ & \text{receiving object,} & \text{product P} \\ & \text{location,} & \text{City D} \\ & \text{degree,} & 10\% \end{bmatrix}$$

Thus, we can extend an undefined affair "to improve market share" to a defined affair "to improve the market share of product P of enterprise E in City D to 10%".

Principle 2.2 From one basic-element, multiple basic-elements with the same characteristic can be extended, and the set of basic-elements with the same characteristic must be non-empty, i.e.

$$B = (O,\quad c,\quad v) -| \{(O_1,\quad c,\quad v_1),\ (O_2,\quad c,\quad v_2),\ \cdots,\ (O_n,\quad c,\quad v_n)\}$$

This principle is obtained from the divergence of "one characteristic and multiple objects".

According to Principle 2.2, when solving contradictory problem, if the problem cannot be solved by one basic-element, it can be considered to use the basic-element composed of other objects with the same characteristics of it to solve the problem.

For example, parts with the same function can be reciprocally replaced, and materials with the same function can be selected by the standard of low cost, etc. which are applications of this thinking. When selecting talents in an enterprise, there are many talents with the same ability, and to solve problems by using this thinking will not make the mistake of "getting into a blind alley".

This principle is also the theoretical basis for value engineering.

Inference 2. 2 One basic-element can be extended to multiple basic-elements with the same characteristic, i.e.

$$B = (O,\quad c,\quad v) -| \{(O_1,\quad c,\quad v),\ (O_2,\quad c,\quad v),\ \cdots,\ (O_n,\quad c,\quad v)\}$$

This inference can be applied in the study on affair-affair matching, for example,

$$A = \text{(creation, dominating object, product A)} -| \begin{cases} A_1 = \text{(production, dominating object, product A)} \\ A_2 = \text{(sales, dominating object, product A)} \\ A_3 = \text{(purchase, dominating object, product A)} \\ A_4 = \text{(complaint, dominating object, product A)} \end{cases}$$

Inference 2.3 One basic-element can be extended to multiple basic-elements with the same object and characteristic; in other words, under different parameters, there can be multiple values of the same object about the same characteristic, i.e.

$$B(t)=\left(O(t),\quad c,\quad v(t)\right)-|\{\left(O(t_1),\quad c,\quad v_1(t_1)\right),\ \left(O(t_2),\quad c,\quad v_2(t_2)\right),\ \cdots,\ \left(O(t_n),\quad c,\quad v_n(t_n)\right)\}$$

The above-mentioned example of using 6 matches to arrange a triangle pattern can be analyzed again by the Inference 2.3.

The basic-elements M_1 and M_2 extended from M, in terms of different moment t_1 and t_2, can be further extended by using Inference 2.3:

$$M_1(t_1)=\left(\text{triangles set } A(t_1),\ \text{location, plane } (t_1)\ \right)-|\,M_{11}(t_2)=\left(\text{triangles set } A(t_2),\ \text{location, space } (t_2)\ \right)$$

$$M_2(t_1)=\left(\text{triangles set } A(t_1),\ \text{triangle side length, } a(t_1)\ \right)-|\,M_{21}(t_3)=\left(\text{triangles set } A(t_3),\ \text{triangle side length, } a'(t_3)\ \right)\ (a'<a)$$

3-dimensinal matter-element formed according to conditional matter-element $l=\left(\text{matches set } B,\ \text{number of matches, } 6\right)$ and from M , M_{11}, M_2

$$M'(t)=\begin{bmatrix}\text{triangles set } A(t), & \text{number of triangles,} & 4(t)\\ & \text{location,} & \text{space } (t)\\ & \text{triangle side length,} & a(t)\end{bmatrix}$$

A real pattern-regular triangular pyramid with 4 regular triangles can be arranged. The 3-dimensional matter-element formed again from M, M_1, M_{21}

$$M''(t')=\begin{bmatrix}\text{triangles set } A(t'), & \text{number of triangles,} & 4(t')\\ & \text{location,} & \text{plane } (t')\\ & \text{triangle side length} & a'(t')\end{bmatrix}$$

i.e. multiple patterns with side length less than match length a can be arranged on the plane, with 4 regular triangles on each pattern, wherein, t and t' indicates different moments.

[**Example 2. 3**] In ancient Greek legend, there was a temple in which two columns were connected by a rope with a complicated knot on it, and the priest announced that the person who could unknot it would surely become a person of great ability and tremendous talent. Many learned men went to have a try but failed, while young Alexander went there, looked at the knot, and thought it could not be unknotted. He immediately drew his sword and cut the knot apart. This was the simplest solution, but why do so many people not like Alexander, for the priest did not say the rope could not be cut apart? This was because of the function of people's habitual domain that let many people artificially add limit to the problem while thinking, rendering "unknot" as an unchangeable objective. Alexander was not confined this way, so he easily solved the problem.

If using the above principle in this example, the solution to contradictory problems can be easily found.

Set objective matter-element as

$$A = \begin{bmatrix} \text{unknot}, & \text{dominating object}, & \text{knot} \\ & \text{acting object}, & \text{person } N \\ & \text{method}, & \text{by hand} \end{bmatrix}$$

Conditional matter-element as

$$A_l = \begin{bmatrix} \text{knotting}, & \text{dominating object}, & \text{knot} \\ & \text{acting object}, & \text{temple priest} \\ & \text{method}, & \text{by hand} \\ & \text{degree}, & \text{dead knot} \end{bmatrix}$$

Then the problem $P=A*A_l$ is a contradictory problem. It's obvious the conditions in this example are unchangeable, so the contradictory problem must be solved by considering extension of the objective, such that

$$A \dashv \begin{cases} A_1 = \begin{bmatrix} \text{scissoring apart} & \text{dominating object}, & \text{knot} \\ & \text{acting object}, & \text{person } N \\ & \text{method}, & \text{by scissor} \end{bmatrix} \\ A_2 = \begin{bmatrix} \text{cutting apart} & \text{dominating object} & \text{knot} \\ & \text{acting object}, & \text{person } N \\ & \text{method}, & \text{by sword} \end{bmatrix} \\ A_3 = \begin{bmatrix} \text{burning apart} & \text{dominating object}, & \text{knot} \\ & \text{acting object}, & \text{person } N \\ & \text{method}, & \text{by fire} \end{bmatrix} \end{cases}$$

……

It can be seen that contradictory problems can be easily solved after extending the problem's objective. Alexander solved the contradictory problem by adopting exactly the compatibility between A_2 and A_l. Actually compatibility also exists between A_1 and A_l, A_3 and A_l, which can be used to solve the contradictory problem in this case.

As to relation-element, the divergence analysis is as follows:

$$R\ (O_r, v_{r1}, v_{r2}, \cdots) \dashv \{ R\ (O_{ri}, v_{r1}, v_{r2}, \cdots),\ (i=1,2,\ldots,n)\}$$

$$\dashv \{ R\ (O_r, v_{r1i}, v_{r2}, \cdots),\ (i=1,2,\ldots,n)\}$$

$$\dashv \{ R\ (O_r, v_{r1}, v_{r2i}, \cdots),\ (i=1,2,\ldots,n)\}$$

$$\dashv \{ R\ (O_r, v_{r1i}, v_{r2j}, \cdots),\ (i=1,2,\ldots,n;\ j=1,2,\ldots,m)\}$$

$$\dashv \{ R\ (O_{ri}, v_{r1j}, v_{r2}, \cdots),\ (i=1,2,\ldots,n;\ j=1,2,\ldots,m)\}$$

$$—|\{ R\ (O_{ri}, v_{r1}, v_{r2j}, \cdots)\ , (i=1,2, \ldots,n; j=1,2, \ldots,m)\}$$

$$—|\{ R\ (O_{ri}, v_{r1j}, v_{r2k}, \cdots)\ , (i=1,2, \ldots,n; j=1,2, \ldots,m; k=1,2, \ldots,p)\}$$

For example,

$$R\ (O_r, v_{r1}, v_{r2}, \cdots) = \begin{bmatrix} \text{teacher-student relation}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & c_{r3}, & 100 \\ & \vdots & \vdots \end{bmatrix}$$

$$—|\left\{ \begin{bmatrix} \text{colleagues relation}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & c_{r3}, & -10 \\ & \vdots & \vdots \end{bmatrix}, \begin{bmatrix} \text{countrymen relationship}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & c_{r3}, & 100 \\ & \vdots & \vdots \end{bmatrix}, \begin{bmatrix} \text{kinship}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & c_{r3}, & 0 \\ & \vdots & \vdots \end{bmatrix}, \cdots \right\}$$

$$—|\left\{ \begin{bmatrix} \text{teacher-student relation}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r21} \\ & c_{r3}, & -1 \\ & \vdots & \vdots \end{bmatrix}, \begin{bmatrix} \text{teacher-student relation}, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r22} \\ & c_{r3}, & 10 \\ & \vdots & \vdots \end{bmatrix}, \cdots \right\}$$

$$—|\left\{ \begin{bmatrix} \text{colleagues relation}, & c_{r1}, & z_1 \\ & c_{r2}, & z_2 \\ & c_{r3}, & -3 \\ & \vdots & \vdots \end{bmatrix}, \begin{bmatrix} \text{countrymen relation}, & c_{r1}, & z_1 \\ & c_{r2}, & z_2 \\ & c_{r3}, & 50 \\ & \vdots & \vdots \end{bmatrix}, \cdots \right\}$$

2.2.2 Principle of Correlative Analysis

Correlative analysis is the analysis of the relation among basic-elements according to the correlation among matter, affair and relation, for better understanding the mechanism of correlation and interaction among matters by formalized method.

Certain dependence between the measures of one basic-element and another basic-element about a certain evaluated characteristic, or between the measures of the same basic-element or of the basic-element of the same group about certain evaluated characteristics, if any, is referred to as correlation.

The following is a general definition of the correlation of a basic-element:

Definition 2.10 Given two sets of basic-elements $\{B_1\}$ and $\{B_2\}$, for any $B_1 \in \{ B_1\}$, if there is at least one $B_2 \in \{ B_2\}$ to let B_1 corresponds to B_2, $\{ B_1\}$ and $\{B_2\}$ are correlative, denoted as $\{B_1\} \tilde{\to} \{ B_2\}$.

In particular, as to the sets of basic-elements $\{B_1\}$ and $\{ B_2\}$ with c_0 as their evaluated characteristic, for any $B_1 \in \{B_1\}$, if there is at least one $B_2 \in \{ B_2\}$ to let $c_0(B_2)=f\ [c_0(B_1)]$, $\{ B_1\}$ and $\{B_2\}$ are correlative about the evaluated characteristic c_0, denoted as

$$\{B_1\} \tilde{\to} (c_0)\{B_2\}.$$

If $c_0(B_2)=f\,[c_0(B_1)]$, and $c_0(B_1)=f^{-1}\,[c_0(B_2)]$, then $\{B_1\}$ and $\{B_2\}$ are mutually correlative about the evaluated characteristic c_0, denoted as $\{B_1\}\sim(c_0)\{B_2\}$.

As to the two evaluated characteristics c_{01} and c_{02}, if $c_{01}(B_1)=f\,[c_{02}(B_1)]$, and $c_{02}(B_1)=f^{-1}\,[c_{01}(B_1)]$, then the evaluated characteristics c_{01} and c_{02} are mutually correlative about the set of basic-elements $\{B_1\}$. The directional correlation is defined similarly.

If $c_{01}(B_1)=f\,[c_{02}(B_2)]$, and $c_{02}(B_2)=f^{-1}\,[c_{01}(B_1)]$, then $\{B_1\}$ and $\{B_2\}$ are mutually correlative about the evaluated characteristics c_{01} and c_{02}. The directional correlation is defined similarly.

As to dynamic basic-elements $B_1(t)$ and $B_2(t)$, if there is f to let $c_0(B_2(t))=f\,[c_0(B_1(t))]$, then $B_1(t)$ and $B_2(t)$ are correlative about the characteristic c_0, denoted as $B_1(t)\tilde{\rightarrow}(c_0)B_2(t)$.

Similarly, the correlation between dynamic basic-elements $B_1(t)\sim B_2(t)$ can be defined. In the situation without causing confusion, it's usually denoted as $B_1\tilde{\rightarrow}B_2$ or $B_1\sim B_2$.

As to basic-element B, we call $Co(B)=(B,c_0,c_0(B))$ a compound basic-element. The knowledge on compound basic-element will be introduced in 2.5. If B is matter-element, and c_0 and B has the same characteristic, then this compound basic-element can be written as matter-element B for short, i.e. if $B=(O_m,c_0,c_0(O_m))$, then $c_0(B)=c_0(O_m)$.

Instruction: in application, unless otherwise stated, correlation is indicated by symbol "~", and by "$\tilde{\rightarrow}$" only when directivity should be indicated in particular.

① AND correlation between one basic-element B and multiple basic-elements B_1, …, B_m, denoted as: $B\sim\bigwedge_{i=1}^{m}B_i$

② OR correlation between one basic-element B and multiple basic-elements B_1, …, B_m, denoted as: $B\sim\bigvee_{i=1}^{m}B_i$

③ Unidirectional AND correlation between one basic-element B and multiple basic-elements B_1, …, B_m, denoted as: $B\tilde{\rightarrow}\bigwedge_{i=1}^{m}B_i$

④ Unidirectional OR correlation between one element B and multiple basic-elements B_1, …, B_m, denoted as: $B\tilde{\rightarrow}\bigvee_{i=1}^{m}B_i$

⑤ Unidirectional AND correlation between multiple basic-elements B_1, …, B_m and one basic-element B, denoted as: $\bigwedge_{i=1}^{m}B_i\tilde{\rightarrow}B$

⑥ Unidirectional OR correlation between multiple basic-elements B_1, …, B_m and one basic-element B, denoted as: $\bigvee_{i=1}^{m}B_i\tilde{\rightarrow}B$

There are similar results of the correlation between multiple basic-elements and multiple basic-elements, which is not dealt with here in detail.

In particular, when the basic-element is matter-element and its evaluated characteristic is the same as the matter-element, definition 2.10 can be modified as:

Definition 2.11 as to dynamic matter-elements

$$M_1(t)=\left(O_{m1}(t),\quad c_{m1},\quad c_{m1}[O_{m1}(t)]\right)$$

$$M_2(t)=\left(O_{m2}(t),\quad c_{m2},\quad c_{m2}[O_{m2}(t)]\right)$$

If $c_{m1}[O_{m1}(t)]=f\left[c_{m2}\left(O_{m2}(t)\right)\right]$, then the matter-elements $M_1(t)$ and $M_2(t)$ are correlative, denoted as $M_1(t)\sim M_2(t)$.

(1) When $c_{m1}=c_{m2}=c_m$, if $c_m[O_{m1}(t)]=f\left[c_m\left(O_{m2}(t)\right)\right]$, then $M_1(t)$ and $M_2(t)$ are correlative matter-elements about characteristic c_m, denoted as $M_1(t)\sim(c_m)\,M_2(t)$.

(2) When $O_{m1}(t)=O_{m2}(t)=O_m(t)$, if $c_{m1}[O_m(t)]=f\left[c_{m2}\left(O_m(t)\right)\right]$, then $M_1(t)$ and $M_2(t)$ are correlative matter-elements about the matter $O_m(t)$, denoted as

$$M_1(t)\sim(O_m)\,M_2(t).$$

This definition shows that: ① when two dynamic matter-elements are matter-elements with the same characteristic, if there is a certain functional relation between the measures of the two matter-elements, these two dynamic matter-elements are correlative, which is sometimes referred to as the correlation of different matters, as a quantitative expression of correlation between matters; ② when two dynamic matter-elements are matter-elements with the same matter, if there is a certain functional relation between the measures of the two matter-elements about two different characteristics, these two dynamic matter-elements are correlative, which is sometimes referred to as correlation between of the same matter, which also shows that correlation also exists between the matter-elements composed of certain different characteristics of the same matter.

Principle 2.3 Given matter-element $M(t)=\left(O_m(t),\quad c_m,\quad c_m\left(O_m(t)\right)\right)$, then there is at least one matter-element with the same characteristic $M_c(t)=\left(O_m^{'}(t),\quad c_m,\quad c_m\left(O_m^{'}(t)\right)\right)$ or matter-element with the same matter $M_O(t)=\left(O_m(t),\quad c_m',\quad c_m'\left(O_m(t)\right)\right)$ or matter-element with different matters $M^{'}(t)=\left(O_m^{'}(t),c_m^{'},c_m^{'}(O_m^{'}(t))\right)$, to let $M(t)\sim M_c(t)$, or $M(t)\sim M_O(t)$, or $M(t)\sim M^{'}(t)$.

It can be seen that utilizing the Principle 2.3 allows formalized and quantitative analysis of the correlations both outside and inside the matters. When contradictory problem cannot be solved by a certain matter-element, other matter-element correlated to it can be considered to be applied. As to correlated matter-elements, the change of measure of one matter-element of them will inevitably cause the change of the other matter-element, which is the basis for the conductive transformation to be introduced hereafter.

[Example 2.4] In order to expand domestic demand and activate market, China implemented reductions of bank interest three times. This scheme mainly adopted the following correlative analysis in economics:

$$M_6(t) = \left(\text{enterprise } O_{m3}(t),\quad \text{loan amount},\quad v_{m6}(t)\right)$$

$$M_5(t) = \left(\text{bank } O_{m2}(t),\quad \text{loan interest rate},\quad v_{m5}(t)\right)$$

$$M_1(t) = \left(\text{consumer } O_{m1}(t),\quad \text{deposit amount},\quad v_{m1}(t)\right)$$

$$M(t) = \left(\text{consumer } O_{m1}(t),\quad \text{purchasing power},\quad v_m(t)\right) \qquad M_4(t) = \left(\text{bank } O_{m2}(t),\quad \text{deposit interest rate},\quad v_{m4}(t)\right)$$

$$M_2(t) = \left(\text{consumer } O_{m1}(t),\quad \text{annual income},\quad v_{m2}(t)\right)$$

$$\cdots\cdots \qquad M_3(t) = \left(\text{consumer } O_{m1}(t),\quad \text{housing source},\quad v_{m3}(t)\right)$$

Therefore, to improve social purchasing power, it's necessary to reduce customer deposit amounts, for which, one direct method is to reduce band deposit interest rates. This is the common method adopted by western countries, i.e. using $M(t) \sim M_1(t) \sim M_4(t)$. However, the social situation at that time in our country was a troop of laid-off workers, combined with the traditional thinking of the Orient, simple implementation of reduction of bank interest did not reduce consumer deposit amounts, but increased it, and surely the social purchasing power was not significantly improved.

Actually, if other relevant factors were considered at the same time: increasing consumer annual income, reducing bank loan interest rates, canceling the welfare houses distribution, and providing more preferential for buying house and car on loan, consumer deposit amount would have been reduced and transformed to investment, to significantly improve the social purchasing power, meeting the objective of expanding domestic demand.

As to affair-element, if the two affairs being conducted at the same moment or the affairs being conducted successively have certain functional relation between the measures of their feasibility, effect, value or cost, it's considered the two affairs are correlative. It's also indicated by this definition that when conducting any affair, other affairs related to the said affair must be taken into full consideration, to avoid "attending to one affair and losing another".

In addition, the correlation of affair-element is closely related to parameter t that may be time, location, or other parameters, and the correlated affair-element at a certain moment may be correlated in less degree or not correlated at another moment; the correlated affair-element at a certain location may be correlated in less degree or not correlated at another location.

2.2.3 Principle of Implication Analysis

The principle of implication analysis is to conduct formalized analysis of matter, affair or relation using basic-elements as formalization tools according to the implications of matter, affair and relation.

The definition of implication of basic-elements is first introduced as follows:

Definition 2.12 Suppose B_1、B_2 are two basic-elements, if B_1 is realized inevitably with the realization of B_2, then the basic-element B_1 implies the basic-element B_2, denoted as $B_1 \Rightarrow B_2$. The "realization of B_i" is usually denoted as "B_i @"$(i = 1,\ 2)$.

Under the condition *l*, if B_1@ exists inevitably with the existence of B_2@, then B_1 implies B_2 under the condition *l*, denoted as $B_1 \Rightarrow (l)\, B_2$.

No matter $B_1 \Rightarrow B_2$, or $B_1 \Rightarrow (l)\, B_2$, we usually call B_1 inferior basic-element, and B_2 superior basic-element.

Definition 2.13 Suppose *B*, B_1 and B_2 are basic-elements,

a) If both B_1 and B_2 are realized inevitably with the realization of *B*, we call AND implication of *B* by B_1 and B_2, denoted as $B_1 \wedge B_2 \Rightarrow B$.

b) If either B_1 or B_2 is realized inevitably with the realization of *B*, we call OR implication of *B* by B_1 and B_2, denoted as $B_1 \vee B_2 \Rightarrow B$.

c) If *B* is realized inevitably with the realization of both B_1 and B_2, we call AND implication of B_1 and B_2 by *B*, denoted as $B \Rightarrow B_1 \wedge B_2$.

d) If *B* is realized inevitably with the realization of either B_1 or B_2, we call OR implication of B_1 or B_2 by *B*, denoted as $B \Rightarrow B_1 \vee B_2$. This principle is similar to c).

Definition 2.13 can be expanded to more general situations:

$$B \Rightarrow \mathop{\wedge}_{i=1}^{n} B_i,\quad B \Rightarrow \mathop{\vee}_{i=1}^{n} B_i,\quad \mathop{\wedge}_{i=1}^{n} B_i \Rightarrow B,\quad \mathop{\vee}_{i=1}^{n} B_i \Rightarrow B$$

Principle 2.4 If $B_1 \Rightarrow B_2$, $B_2 \Rightarrow B_3$, then $B_1 \Rightarrow B_3$, or denoted as $B_1 \Rightarrow B_2 \Rightarrow B_3$.

The following inference can be obtained from definition 2.13 and principle 2.4:

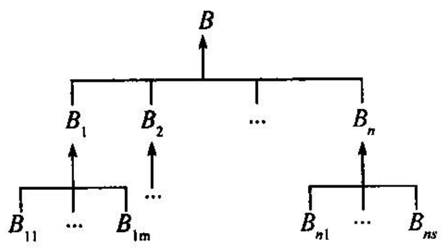
Inference 2.4 (1) If $B_{11} \wedge B_{12} \Rightarrow B_1$, $B_{21} \wedge B_{22} \Rightarrow B_2$, and $B_1 \wedge B_2 \Rightarrow B$, then

$$B_{11} \wedge B_{12} \wedge B_{21} \wedge B_{22} \Rightarrow B \ .$$

(2) If $B_{11} \vee B_{12} \Rightarrow B_1$, $B_{21} \vee B_{22} \Rightarrow B_2$, 且 $B_1 \vee B_2 \Rightarrow B$, then

$$B_{11} \vee B_{12} \vee B_{21} \vee B_{22} \Rightarrow B \ .$$

It’s shown by inference 2.4 that, in AND implication, the most inferior basic-element as a whole implies the most superior basic-element; in OR implication, each most inferior basic-element implies the most superior basic-element. The system formed from this inference is referred to as a basic-element implication system or BEIS for short. The general form of basic-element implication system is as follows:



The above implication system may be AND implication system or OR implication system, or AND-OR implication system, from which it can be seen that the implication system can be multilayered. When the superior basic-element is difficult to be realized, we can look for its inferior basic-element, and if the inferior basic-element can be easily realized, it’s considered that the approach to solve contradictory problem has been found.

[Example 2.5] If one brought a car, he must buy gas, buy or rent a parking space and pay compulsory insurance, etc., while to buy gas, he must go to the gas station which can be analyzed by the following implication system:

$$A = (\text{buy}, \quad \text{dominating object}, \quad \text{car})$$

$$\Downarrow$$

$A_1 = [\text{buy}, \quad \text{dominating object}, \quad \text{gas}]$ $A_2 = (\text{buy}, \quad \text{dominating object}, \quad \text{parking lot})$ $A_3 = (\text{pay}, \quad \text{dominating object}, \quad \text{compulsory insurance})$

$\Downarrow$ $\Downarrow$ $\Downarrow$

$A_{11} = (\text{go}, \quad \text{dominating object}, \quad \text{gas station})$ $A_{21} = (\text{go}, \quad \text{dominating object}, \quad \text{parking lot})$ $A_{31} = (\text{go}, \quad \text{dominating object}, \quad \text{insurance company})$

According to this implication system, the gas station, parking space and insurance company can prepare marketing schemes pertinent to car owners to achieve higher profit.

2.2.4 Principle of Opening-up Analysis

The possibilities of composing, decomposing and expanding/contracting affair, matter and relation are referred to respectively as composability, decomposability, and expandability/contractability, collectively, expandability.

By composability, one matter can combine with other matter to generate new matter, to provide possibility for solving contradictory problems; by decomposability, one matter can be decomposed into several new matters with certain characteristics that are not owned by the original matter, to provide possibility for solving contradictory problems; similarly, one matter can be expanded or contracted to provide possibility for solving contradictory problems,

After an affair, matter and relation are expressed by basic-element, opening-up analysis of the basic-element can be conducted, including the analyses of composability, decomposability and expandability/contractability.

(1) Composability Analysis

Principle 2.5 Given a basic-element B_1= (O_1, c_1, v_1), then there is at least one basic-element B_2=(O_2, c_2, v_2) to allow B_1 and B_2 to be composed into B, we call B_2 composable basic-element of B_1, hear

$$B=B_1 \oplus B_2=\begin{cases} (O_1, c_1 \oplus c_2, v_1 \oplus v_2) = \begin{bmatrix} O_1, & c_1, & v_1 \\ & c_2, & v_2 \end{bmatrix}, & \text{when } O_1=O_2,\ c_1\neq c_2; \\ (O_1 \oplus O_2, c_1, v_1 \oplus v_2), & \text{when } O_1\neq O_2,\ c_1=c_2; \\ \begin{bmatrix} O_1 \oplus O_2, & c_1, & v_1 \oplus c_1(O_2) \\ & c_2, & c_2(O_1) \oplus v_2 \end{bmatrix}, & \text{when } O_1\neq O_2,\ c_1\neq c_2; \end{cases}$$

The composable basic-element of B_1 as a whole is denoted as {B_2}, and B_1 is extended to {$B_1 \oplus B_2$}, which is referred to as composability analysis, denoted as

$$B_1 \dashv \{B_1 \oplus B_2\}, \text{ wherein } B_2 \in \{B_2\}.$$

(2) Decomposability Analysis

Principle 2.6 Any basic-element can be decomposed into several basic-elements under certain condition, i.e. suppose, B=(O, c, $c(O)$)and B_i=(O_i, c, $c(O_i)$), then under certain condition ℓ, about a certain characteristic c, we have

$$(O, c, c(O))//(\ell)\{(O_1, c, c(O_1)), (O_2, c, c(O_2)), \ldots, (O_m, c, c(O_m))\}$$

denoted as $B//\{B_1, B_2, \ldots, B_m\}$.

It's obvious that there are different decomposing forms under different conditions, i.e. B can be decomposed into multiple sets of basic-elements B_i= {B_{i1}, B_{i2}, …, B_{im_i} },i=1,2,…,n. The extension of B to {B_i} is referred to as decomposability analysis of B, denoted as $B \dashv \{B_i\}$, i=1,2,…,n.

(3) Expandability/Contractability Analysis

Principle 2.7 Any basic-element can be expanded or contracted under certain condition, i.e. suppose B = (O, c, v), under certain condition ℓ, there must be a real number α (α >0) to allow αB=(αO, c, αv)). When 0< α <1, the basic-element B can be contracted to αB; when α >1, the basic-element can be expanded to αB, wherein, αO indicates the object O with measure of αv.

As to matter-element, composability analysis has two forms: increasability analysis and integrability analysis.

Principle 2.8 Given matter-element $M_1 = (O_{m1},\ \ c_{m1},\ \ c_{m1}(O_{m1}))$, there is at least one matter-element

$$M_2 = (O_{m2},\ \ c_{m2},\ \ c_{m2}(O_{m2}))$$

wherein, O_{m1} and O_{m2} can constitute polymer, i.e. O_{m1} and O_{m2} are increasable matters, let

$$M_1 \oplus M_2 = \begin{cases} (O_{m1} \oplus O_{m2},\ \ c_{m1},\ \ c_{m1}(O_{m1}) \oplus c_{m1}(O_{m2})), & c_{m1} = c_{m2} \\ \begin{bmatrix} O_{m1} \oplus O_{m2}, & c_{m1}, & c_{m1}(O_{m1}) \oplus c_{m1}(O_{m2}) \\ & c_{m2}, & c_{m2}(O_{m1}) \oplus c_{m2}(O_{m2}) \end{bmatrix}, & c_{m1} \neq c_{m2} \end{cases}$$

This principle is referred to as the principle of increasability analysis of matter-elements M_1 and M_2.

In particular, when $O_{m1} = O_{m2}$, $c_{m1} \neq c_{m2}$, we have

$$M_1 \oplus M_2 = \begin{bmatrix} O_{m1}, & c_{m1}, & c_{m1}(O_{m1}) \\ & c_{m2}, & c_{m2}(O_{m1}) \end{bmatrix}$$

i.e. two matter-elements with the same matter and different characteristic can constitute a 2-dimensional matter-element.

[Example 2.6] Suppose $M_1 = (\text{product } A,\ \ \text{function},\ \ a) = (O_{m1},\ \ c_{m1},\ \ c_{m1}(O_{m1}))$, according to principle **2.8**, we can find at least one matter-element

$M_2 = (\text{product } B,\ \ \text{aesthetic degree},\ \ b) = (O_{m2},\ \ c_{m2},\ \ c_{m2}(O_{m2}))$, let

$$M_1 \oplus M_2 = \begin{bmatrix} O_{m1} \oplus O_{m2}, & c_{m1}, & c_{m1}(O_{m1}) \oplus c_{m1}(O_{m2}) \\ & c_{m2}, & c_{m2}(O_{m1}) \oplus c_{m2}(O_{m2}) \end{bmatrix}$$

$$= \begin{bmatrix} \text{product } A \oplus \text{ product } B, & \text{function}, & a \oplus a_1 \\ & \text{aesthetic degree}, & b_1 \oplus b \end{bmatrix}$$

This increasability analysis of matter-element indicates that when one certain matter-element cannot meet the requirement for solving the problem, it can be considered to add another matter-element to let the two be combined to solve the problem. If M_1 fails to attract customers while M_2 can render customers a surprise, then $M_1 \oplus M_2$ will achieve the objective of promotion.

According to this principle, if adopting merely one matter-element cannot transform contradictory problems to compatible problems, it can be considered to polymerize multiple matter-elements to solve the contradictory problem.

Principle 2.9 Given matter-element $M_1=\left(O_{m1},\quad c_{m1},\quad c_{m1}(O_{m1})\right)$, then there is at least one matter-element with the same dimension

$$M_2=\left(O_{m2},\quad c_{m2},\quad c_{m2}(O_{m2})\right)$$

Let M_1 and M_2 constitute a new matter-element, wherein, O_{m1} and O_{m2} can constitute a system, here O_{m1} and O_{m2} are integrable, i.e.

$$M_1\otimes M_2=\begin{cases}\left(O_{m1}\otimes O_{m2},\quad c_{m1}\otimes c_{m2},\quad c_{m1}(O_{m1})\otimes c_{m2}(O_{m2})\right)\ , & \text{when } \mathrm{c}_{m1} \text{ and } \mathrm{c}_{m2} \text{ are integrable}\\ \begin{bmatrix}O_{m1}\otimes O_{m2}, & c_{m1}, & c_{m1}(O_{m1}\otimes O_{m2})\\ & c_{m2}, & c_{m2}(O_{m1}\otimes O_{m2})\end{bmatrix}\ , & \text{when } c_{m1} \text{ and } \mathrm{c}_{m2} \text{ are not integrable}\end{cases}$$

This principle is referred to as the principle of integrability analysis of matter-elements M_1 and M_2.

In particular, when $O_{m1}\neq O_{m2}$ and $c_{m1}=c_{m2}$, we have

$$\begin{aligned}M_1\otimes M_2&=\left(O_{m1}\otimes O_{m2},\quad c_{m1},\quad c_{m1}(O_{m1})\otimes c_{m1}(O_{m2})\right)\\ &\underline{\underline{\Delta}}\left(O_{m1}\otimes O_{m2},\quad c_{m1},\quad c_{m1}(O_{m1}\otimes O_{m2})\right)\end{aligned}$$

where $c_{m1}(O_{m1}\otimes O_{m2})=c_{m1}(O_{m1})\otimes c_{m1}(O_{m2})$.

When $O_{m1}=O_{m2}$, $c_{m1}\neq c_{m2}$, we have

$$M_1\otimes M_2=\begin{cases}\left(O_{m1},\quad c_{m1}\otimes c_{m2},\quad c_{m1}(O_{m1})\otimes c_{m2}(O_{m1})\right), & \text{when } c_{m1} \text{ and } c_{m2} \text{ are integrable}\\ \begin{bmatrix}O_{m1}, & c_{m1}, & c_{m1}(O_{m1})\\ & c_{m2}, & c_{m2}(O_{m1})\end{bmatrix}\ , & \text{when } c_{m1} \text{ and } c_{m2} \text{ are not integrable}\end{cases}$$

Principles 2.8 and 2.9 are two forms of matter-element composition, and the former is essentially polymerization while the latter is essentially system constitution.

[Example 2.7] Suppose $M_1=\left(\text{lamp tube } A,\quad \text{power},\quad 40\text{W}\right)$, $M_2=\left(\text{lamp holder } B,\quad \text{length},\quad 1\text{m}\right)$, then

$$M_1\oplus M_2=\begin{bmatrix}\text{lamp tube } A\oplus \text{ lamp holder } B, & \text{power}, & 40\text{W}\oplus\phi\\ & \text{length}, & a\text{m}\oplus 1\text{m}\end{bmatrix}$$

It's shown that lamp tube A with power of 40W and length of *a*m is polymerized with lamp holder B with length of 1m. Whether these two matter-elements can constitute a system depends on the evaluation of *a*. In general, for matching of lamp tube and holder, certain requirements must be met, now, M_1 and M_2 constitute system, i.e.

$$M_1 \otimes M_2 = \begin{bmatrix} \text{lamp tube } A \otimes \text{lamp holder } B, & \text{power}, & 40\text{W} \\ & \text{length}, & 1\text{m} \otimes 1\text{m} \end{bmatrix} = \begin{bmatrix} \text{fluorescent lamp } C, & \text{power}, & 40\text{W} \\ & \text{length}, & 1\text{m} \end{bmatrix}$$

Principle 2.9 is also the theoretical basis for the practice of "supplementing deficiency by sufficiency". In case of disadvantageous condition, the advantageous condition combined with it can be found by divergence analysis to solve the contradiction.

In addition, according to principle 2.9, as to the system constituted by *n* matter-elements with the same characteristic, the effect of composition can be judged by the size of measure of certain function before and after the composition, i.e. if

$$M_1 = (O_{m1},\ c_m,\ c_m(O_{m1})),\ M_2 = (O_{m2},\ c_m,\ c_m(O_{m2})),\ \ldots,\ M_n = (O_{mn},\ c_m,\ c_m(O_{mn})),$$

$$\begin{aligned} M_1 \otimes M_2 \otimes \cdots \otimes M_n &= (O_{m1} \otimes O_{m2} \otimes \cdots \otimes O_{mn},\ c_m,\ c_m(O_{m1}) \otimes c_m(O_{m2}) \otimes \cdots \otimes c_m(O_{mn})) \\ &\underline{\underline{\Delta}} (O_m,\ c_m,\ c_m(O_m)) \end{aligned}$$

The relations between $c_m(O_m)$ and the sum of original measures $\sum_{i=1}^{n} c_m(O_{mi})$ can be in three cases as follows:

(1) In case of $c_m(O_m) > \sum_{i=1}^{n} c_m(O_{mi})$, it's shown that the measure after composition is larger than the sum of original measures;

(2) In case of $c_m(O_m) = \sum_{i=1}^{n} c_m(O_{mi})$, it's shown that the measure after composition is equal to the sum of original measures;

(3) In case of $c_m(O_m) < \sum_{i=1}^{n} c_m(O_{mi})$, it's shown that the measure after composition is less than the sum of original measures.

It's also shown the different results from "three heads are better than one" and from "three boys no boy" are caused by the internal relations after composition.

Principle 2.10 If $O_m = O_{m1} \otimes O_{m2} \otimes \cdots \otimes O_{mn}$, i.e. O_m is a decomposable matter:

$O_m // \{O_{m1}, O_{m2}, \cdots O_{mn}\}$, then for any one characteristic c_m, we have:

$$(O_m,\ c_m,\ c_m(O_m))//\{(O_{m1},\ c_m,\ c_m(O_{m1})),\ (O_{m2},\ c_m,\ c_m(O_{m2})),\ \cdots,\ (O_{mn},\ c_m,\ c_m(O_{mn}))\}$$

And the relations between the matter measure before decomposition $c_m(O_m)$ and the sum of measures of matters after composition $\sum_{i=1}^{n} c_m(O_{mi})$ can be in three cases as follows:

(1) In case of $\sum_{i=1}^{n} c_m(O_{mi}) > c_m(O_m)$, it's shown that the sum of measures of matters after decomposition about characteristic c_m is bigger than the measure of the original matter O_m about c_m;

(2) In case of $\sum_{i=1}^{n} c_m(O_{mi}) = c_m(O_m)$, it's shown that the sum of measures of matters after decomposition about characteristic c_m is equal to the measure of the original matter O_m about c_m;

(3) In case of $\sum_{i=1}^{n} c_m(O_{mi}) < c_m(O_m)$, it's shown that the sum of measures of matters after decomposition about characteristic c_m is less than the measure of the original matter O_m about c_m.

Using Principle **2.10** can analyze whether matter decomposition can help to solve contradictory problems.

[Example 2.8] A handful of chopsticks O_m are composed of 10 chopsticks $O_{m1},\ O_{m2},\cdots,\ O_{m10}$, i.e.

$$O_m = O_{m1} \otimes O_{m2} \otimes \cdots \otimes O_{m10}$$

Suppose c_1 is strength characteristic, denoted by $M_1 = (O_m,\ c_1,\ v_1), M_{1i} = (O_{mi},\ c_1,\ v_{1i}), i = 1, 2, \cdots, 10$, thus we have

$$v_1 > \sum_{i=1}^{10} v_{1i}$$

Suppose c_2 is weight characteristic, denoted by $M_2 = (O_m,\ c_2,\ v_2), M_{2i} = (O_{mi},\ c_2,\ v_{2i}), i = 1, 2, \cdots, 10$, thus we have

$$v_2 = \sum_{i=1}^{10} v_{2i}$$

Suppose c_3 is length characteristic, denoted by $M_3 = (O_m,\ c_3,\ v_3), M_{3i} = (O_{mi},\ c_3,\ v_{3i}), i = 1, 2, \cdots, 10$, thus we have

$$v_3 < \sum_{i=1}^{10} v_{3i}$$

2. 3 Principle of Conjugate Analysis

The study on matter structure can help us solve contradictory problem by utilizing every component of the matter. System theory that studies matter by components and internal/external relations of the system is the description of one aspect of matter structure. Through analysis of matter, we found that, except for systematic property, the matter structure can be studied by its physical property, dynamic property and antithetic property. For example, in the period of Three Kingdoms, Zhuge Liang, only having thousands of remaining troops made up of the old and weak, could force Sima Yi who had one hundred thousand picked troops to retreat without the courage to have a fight, he succeeded in presenting a bold front to conceal a weak force, definitely not using the physical part – thousands of remaining troops made up of the old and weak, but using the non-physical part – his reputation of “being prudent throughout his lifetime”. Therefore, while studying matter structure, we should study not only its physical part but also its non-physical part. In addition, in terms of the dynamic property of matter, all matters have both apparent and latent parts, and in terms of the antithetic property of matter, all matters have both negative and positive aspects.

2.3.1 Conjugacy – All-Round Understanding of Matter

Understanding the matter from its physical, systematic, dynamic and antithetic properties can let us completely understand a matter’s structure, and more profoundly discover the nature of development and change of matters. Embarking from these four angles, we correspondingly proposed four pairs of concepts: imaginary and real, soft and hard, latent and apparent, and negative and positive to describe a matter’s constitution, referred to as the matter’s conjugacy. Careful study on a matter’s conjugacy and its reciprocal transformations can provide new methods for solving contradictory problems.

1. Imaginary Part and Real Part

In terms of physical property of matter, all matters are composed of a physical part and a non-physical part, the former is referred to as the real part of matter and the latter is referred to as the imaginary part of matter. A matter is a matter only by combination of a real part as its basis and an imaginary part as its purpose. Walls, ceiling, floors and other physical parts of a house belong to the real part which encloses the space (imaginary part) wherein we live; a product’s entity is its real part, while its brand and image, etc. are its imaginary part; a person’s body and clothes are the real part, while its temperament, image, reputation and knowledge, etc., are its imaginary part. In terms of an enterprise, assets, facilities, workshops, products, staff and other entities are its real part, while the enterprise image, technical status and management status, etc. are the enterprise’s imaginary part.

When solving a contradictory problem, both real and imaginary parts of matter shall be noticed, for sometimes it’s required to use the real part to solve the contradictory problem of the imaginary part, while sometimes it’s required to use the imaginary part to solve the contradictory problem of the real part.

There may be a mid-part between the imaginary part and the real part, referred to as the imaginary-real mid-part. Taking an empty cup as an example, its spatial part is a portion of its imaginary part, but when the cup is filled with some water, the cup has both a real part (water) and an imaginary part (space), which are transforming with the change of water amount, and when the water is gone, the spatial part completely becomes the imaginary part. Here, the space containing water is called the imaginary-real mid-part. The channels and collaterals of the human body may also be the imaginary-real mid-part.

2. Soft Part and Hard Part

When considering a matter's structure in terms of the matter's systematic property, the matter's components as a whole are referred to as the hard part of matter, the relations between the matter and its components and other matters than the said matter are referred to as the soft part of the matter. There are two Chinese sayings: "one boy is a boy, two boys half a boy, and three boys no boy"; "three heads are better than one", which show that three persons may result in completely different results according to good or poor combination. Therefore, for studying on matter, only study on its components is far from enough, but deepening study on its internal and external relations must be conducted. In case of a failed machine, sometimes all of its components are in good condition, and the failure may result from poor contact at a certain connection (soft part), or line disconnection, so the source of failure cannot be found even if each component is inspected, without noticing the soft part during inspection.

Matter's soft part is made up of the relation between the matter's components (internal subordinate relation), relation between the matter and its subordinate matters (external subordinate relation), and relation between the matter and other matters (external associative relation).

If the function of certain components of the matter is to connect with the other two components, this component is both the hard part and the soft part of the matter. For easy analysis of matter's systematic property, this kind of part is referred to as the matter's soft-hard mid-part. For example, all wires connecting computer, screen and printer are referred to as the computer's soft-hard mid-part.

When solving contradictory problems, understanding on matter must not be merely limited in its hard part and soft part, and the alleged "the whole ≠ the sum of its parts", and "1+1≠2", all indicate that the soft part and hard part are interacting and interplaying.

3. Latent Part and Apparent Part

In terms of a matter's dynamic property, any matter is changing continuously, for stagnation is ever-relative while motion is permanent. Disease has its latent period, seed has its incubation period of germination, and an egg can hatch into chicken at a certain temperature and after a certain time. The matter's latent parts are referred to as the matter's latent part, and apparent parts are referred to as its apparent part.

The latent part of some matters may become apparent under certain conditions, for example, the embryo in womb (latent person) will become apparent as an infant (apparent person); the latent part of some matters may not become apparent in certain conditions, for example, seed cannot germinate being short of water; the latent part of some matters may be empty set; the apparent part of some matters may have latent function or characteristic, for example, some beverage bottles have the latent function as a cup, and an idle air conditioner has latent electric consumption; the apparent part of some matters may have latent risk, for example, the battery of a portable computer may cause a computer explosion at an excessive temperature. The latent part of some matters may have an apparent function or characteristic, for example, the embryo in the womb can move, and need absorbing nutrition, and has weight, etc. There must be a criticality in the process of reciprocal transformation between latent parts and apparent parts, the part at criticality is referred to as the latent-apparent mid-part, such as the chicken before pipping, and the embryo before childbirth, etc.

4. Negative Part and Positive Part

In terms of matter's antithetic property, all matters have two parts that are antithetic. The antithetic property of matter is subject to one certain characteristic, and the measure of matter about certain characteristics results from the comprehensive function of the part producing a positive value and the part producing a negative value inside the matter. The part producing the positive value in the measure of matter about certain characteristic is referred to as the positive part of matter about the said characteristic, and the part producing the negative value in the measure of matter about a certain characteristic is referred to as the negative part of matter.

Between the negative part and the positive part, there is also the part with zero value about certain characteristics, for example, the measure of the organization with balanced income and consumption in an enterprise is zero in terms of profits. The part of zero in the measure value of matter about certain characteristic is referred to as the positive-negative mid-part of matter about the said characteristic.

"Positive-negative" and "advantageous-disadvantageous" are different. For example, in terms of enterprise profits, waste water, gas and waste residue should be disposed, which have a negative value of measure about profits, so they are the negative parts of the enterprise; "three wastes", for causing environmental pollution, are disadvantages of enterprise. In terms of enterprise profits, employees' welfare department, kindergarten, and publicity department, etc. have negative value of measure about profits, being the negative parts of enterprise, but these parts will improve employees' job enthusiasm and promote enterprise image, so they are the "advantageous" parts of the enterprise. In other words, the negative part about certain characteristics may be the part advantageous to the matter or the part disadvantageous to the matter.

2.3.2 Principle of Conjugate Analysis

Matter conjugate analysis includes imaginary-real conjugate analysis, soft-hard conjugate analysis, negative-positive conjugate analysis, and latent-apparent conjugate analysis.

The matters involved in a problem, no matter the subject, object, or resource, should be subject to the following principle of conjugate analysis.

Principle 2.11 All matters have conjugate parts, and the sum of each pair of conjugate parts and its mid-part equals to the original matter, i.e. supposing certain matter is O_m, with real part $\mathrm{re}(O_m)$, imaginary part $\mathrm{im}(O_m)$ and imaginary-real mid-part $\mathrm{mid}_{\text{re-im}}(O_m)$, soft part $\mathrm{sf}(O_m)$, hard part $\mathrm{hr}(O_m)$ and soft-hard mid-part $\mathrm{mid}_{\text{sf-hr}}(O_m)$, latent part $\mathrm{lt}(O_m)$, apparent part $\mathrm{ap}(O_m)$ and latent-apparent mid-part $\mathrm{mid}_{\text{lt-ap}}(O_m)$, and negative part $\mathrm{ng}_c(O_m)$, positive part $\mathrm{ps}_c(O_m)$ and negative-positive mid-part $\mathrm{mid}_{\text{ng-ps}}(O_m)$ about characteristic c, then

$$
\begin{aligned}
O_m &= \mathrm{re}(O_m) \oplus \mathrm{im}(O_m) \oplus \mathrm{mid}_{\text{re-im}}(O_m) \\
&= \mathrm{hr}(O_m) \oplus \mathrm{sf}(O_m) \oplus \mathrm{mid}_{\text{sf-hr}}(O_m) \\
&= \mathrm{lt}(O_m) \oplus \mathrm{ap}(O_m) \oplus \mathrm{mid}_{\text{lt-ap}}(O_m) \\
&= \mathrm{ng}_c(O_m) \oplus \mathrm{ps}_c(O_m) \oplus \mathrm{mid}_{\text{ng-ps}}(O_m)
\end{aligned}
$$

Because of limited capacity of understanding, the mid-part between every conjugate part is not separately studied at present, but attributed to certain conjugate parts for discussion according to the requirement of the actual problem. In terms of certain matters, their certain conjugate part and/or mid-part may be empty. For example, as to a music disc, the disc is its real part while the music in it is its imaginary part; while the so-called blank disc is actually a disc with a blank imaginary part. As to a dead ancestor, its entity does not exist, while its imaginary part of reputation and spirit, etc. does exit.

Principle 2.12 Each conjugate part of any matter has numerous characteristics, and each conjugate part can be expressed by a multi-dimensional basic-elements or formalization of its composition, within which, the imaginary part, real part, hard part, latent part, apparent part, negative part and positive part can be expressed by a multi-dimensional matter-element or composition of multi-dimensional matter-element, and the soft part can be expressed by a multi-dimensional relation-element or composition of a multi-dimensional relation-element. For example,

$$M_{\mathrm{re}}=\begin{bmatrix} \mathrm{re}(O_m), & c_{\mathrm{re}_1}, & v_{\mathrm{re}_1} \\ & c_{\mathrm{re}_2}, & v_{\mathrm{re}_2} \\ & \vdots & \vdots \\ & c_{\mathrm{re}_{n_1}}, & v_{\mathrm{re}_{n_1}} \end{bmatrix}$$ indicates real part matter-element;

$$M_{\mathrm{im}}=\begin{bmatrix} \mathrm{im}(O_m), & c_{\mathrm{im}_1}, & v_{\mathrm{im}_1} \\ & c_{\mathrm{im}_2}, & v_{\mathrm{im}_2} \\ & \vdots & \vdots \\ & c_{\mathrm{im}n_2}, & v_{\mathrm{im}n_2} \end{bmatrix}$$ indicated imaginary part matter-element;

$$M_{\mathrm{hr}}=\overset{s}{\underset{i=1}{\wedge}}\begin{bmatrix} \mathrm{hr}_i(O_m), & c_{\mathrm{hr}_{1i}}, & v_{\mathrm{hr}_{1i}} \\ & c_{\mathrm{hr}_{2i}}, & v_{\mathrm{hr}_{2i}} \\ & \vdots & \vdots \\ & c_{\mathrm{hr}_{ni}}, & v_{\mathrm{hr}_{ni}} \end{bmatrix}$$ indicates the part matter-element as a whole of s parts in the hard part;

$$M_{\mathrm{sf}}=\overset{t}{\underset{i=1}{\wedge}}\begin{bmatrix} \mathrm{sf}_i(O_m), & c_{\mathrm{sf1i}}, & v_{\mathrm{sf1i}} \\ & c_{\mathrm{sf2i}}, & v_{\mathrm{sf2i}} \\ & \vdots & \vdots \\ & c_{\mathrm{sfni}}, & v_{\mathrm{sfni}} \end{bmatrix}$$

indicates the soft part matter-element as a whole of t parts in the soft part;

Principle 2.13 In a pair of conjugate parts of any one matter, one certain conjugate part has at least one characteristic that is relevant to certain characteristic of its corresponding conjugate part, i.e.

(1) Every matter has an imaginary part and a real part, and in the imaginary part and the real part of the same matter, there is at least one characteristic of imaginary parts that is relevant to one characteristic of the real part;

(2) Every matter has a soft part and a hard part, and in the soft part and the hard part of the same matter, there is at least one characteristic of the soft part that is relevant to one characteristic of the hard part;

(3) Every matter has a negative part and a positive part, and in the negative part and the positive part of the same matter, there is at least one characteristic of the negative part that is relevant to one characteristic of the positive part;

(4) Every matter has a latent part and an apparent part, and in the latent part and the apparent part of the same matter there is at least one characteristic of the latent part that is relevant to one characteristic of the apparent part.

It can be known from the above principle that, for all-around analysis of matter, we must analyze from its every conjugate part, analyze not only the constitution of every conjugate part, but also its correlation with the corresponding conjugate part, only in this way can we avoid the mistakes of “taking a part for the whole” and “attending to one thing and losing another”.

2.4 Extension Transformation

The tool for solving contradictory problems is extension transformation. Through certain extension transformations, unknowable problems can be transformed to knowable problems, unfeasible problems can be transformed to feasible problems, false propositions can be transformed to true propositions, and wrong inferences can be transformed to correct inferences. These transformations are the commonly referred ideas, tips and methods. In this section we will introduce the general concept and types of extension transformation, conductive transformation, as well as the nature and operation of extension transformation, etc.

2.4.1 General Concept of Extension Transformation

The transformations adopted in Extenics are collectively referred to as extension transformation, and its general definition is given in formalized language as follows.

1. General Definition of Extension Transformation

Definition 2.14 Suppose object $\Gamma_0 \in \{M, A, R, C_o, k, U\}$ (i.e. Γ_0 is any object in matter-element, affair-element, relation-element, compound-element①, criterion, and any object in the universe of discourse), and the transformation from Γ_0 to the object of the same class Γ or multiple objects in the same class Γ_1, $\Gamma_2, \ldots, \Gamma_n$ is referred to as extension transformation of object Γ_0, denoted as

$$T\Gamma_0=\Gamma$$

$$\text{or} \qquad T\Gamma_0=\{\Gamma_1, \Gamma_2, \ldots, \Gamma_n\}$$

If any extension transformation is actively implemented, it’s called active extension transformation, commonly referred to as extension transformation for short; if a certain extension transformation is caused by other extension transformations, it’s called conductive transformation.

In particular, transformation e is referred to as unitary transformation. It’s obvious that $e\Gamma_0=\Gamma_0$.

Note: ① for definition of compound-element, see also section 2.5.

2. Connotation of Extension Transformation

Extension transformation is the transformation of one object to another object or decomposition of one object into several objects. Extension transformation can be expressed in the form of an affair-element as:

$$T=\begin{bmatrix} O_T, & c_{T1}, & v_{T1} \\ & c_{T2}, & v_{T2} \\ & c_{T3}, & v_{T3} \\ & c_{T4}, & v_{T4} \\ & c_{T5}, & v_{T5} \\ & c_{T6}, & v_{T6} \\ & c_{T7}, & v_{T7} \\ & \vdots & \vdots \end{bmatrix}=\begin{bmatrix} \text{transformation}, & \text{dominating object}, & v_{T1} \\ & \text{receiving object}, & v_{T2} \\ & \text{transformation result}, & v_{T3} \\ & \text{acting object}, & v_{T4} \\ & \text{method}, & v_{T5} \\ & \text{tool}, & v_{T6} \\ & \text{time}, & v_{T7} \\ & \vdots & \vdots \end{bmatrix}$$

wherein, O_T is the name of action, indicating the name of the implemented transformation, i.e.

$$O_T \in \{\text{substitution, decomposition, increasing, decreasing, expansion, contraction, etc.}\}$$

O_T can be determined by extensible analysis or conjugate analysis of the object of planned transformation.

The above transformation T can be analyzed as: at time v_{T7}, by tool v_{T6} and method v_{T5}, v_{T4} implements transformation O_T of v_{T1}, with transformation quantity v_{T2} and transformation result v_{T3}. This transformation is commonly denoted as

$$T\, v_{T1} = v_{T3}$$

wherein, v_{T5} and v_{T6} can be determined by historical information, artificial designation or experience, etc. Determination of v_{Ti} and i=1, 2, means the determination of extension transformation T.

3. Basic Transformations

Suppose $\Gamma \in \{O_m, c_m, v_m, O_a, c_a, v_a, O_r, c_r, v_r, M, A, R, Co, k, U\}$, wherein, Co indicates compound-element, k indicates dependent criterion, U indicates universe of discourse and others idem.

Γ may have basic transformation in the following five forms:

(1) Substitution transformation: $T\Gamma = \Gamma'$, i.e.

$$T = \begin{bmatrix} \text{substitution}, & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma \\ & c_{T3}, & \Gamma' \\ & \vdots & \vdots \end{bmatrix}$$

(2) Increasing/decreasing transformation:

Increasing transformation, suppose $T_1\Gamma = \Gamma \oplus \Gamma_1$, i.e.

$$T_1 = \begin{bmatrix} \text{increasing}, & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma_1 \\ & c_{T3}, & \Gamma \oplus \Gamma_1 \\ & \vdots & \vdots \end{bmatrix},$$

Decreasing transformation: $T_2\Gamma = \Gamma \ominus \Gamma_1$, i.e.

$$T_2 = \begin{bmatrix} \text{decreasing}, & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma_1 \\ & c_{T3}, & \Gamma \ominus \Gamma_1 \\ & \vdots & \vdots \end{bmatrix}$$

(3) Expansion/contraction transformation: $T\Gamma = \alpha\Gamma$, i.e.

$$T = \begin{bmatrix} \text{expansion} \vee \text{contraction}, & c_{T1}, & \Gamma \\ & c_{T2}, & \alpha \text{ multiples} \\ & c_{T3}, & \alpha\Gamma \\ & \vdots & \vdots \end{bmatrix},$$

It is expansion transformation when $\alpha>1$, and contraction transformation when $0<\alpha<1$.

(4) Decomposition transformation: $T\Gamma=\{\Gamma_1,\Gamma_2,\ldots,\Gamma_n\}$, wherein, $\Gamma_1\oplus\Gamma_2\oplus\ldots\oplus\Gamma_n=\Gamma$, i.e.

$$T=\begin{bmatrix}\text{decomposition,} & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma_1\oplus\Gamma_2\oplus\ldots\oplus\Gamma_n=\Gamma \\ & c_{T3}, & \{\Gamma_1,\Gamma_2,\ldots,\Gamma_n\} \\ & \vdots & \vdots\end{bmatrix}.$$

(5) Duplication transformation: Duplication is a special basic transformation, such as photo-processing, copying, scanning, printing, disc carving, sound recording, video recording, the method of reuse, and reproduction of products, etc. This kind of transformation is extensively applied in the field of information. Batch production is also a kind of duplication, including the duplication of both real parts and imaginary parts. The provided conditions can be divided into two types: one type of conditions can be reused; the other type of conditions cannot be duplicated, but can be distributed for use only. Duplication transformation is denoted as

$$T=\begin{bmatrix}\text{duplication,} & c_{T1}, & \Gamma \\ & c_{T2}, & \Gamma^* \\ & c_{T3}, & \{\Gamma,\Gamma^*\} \\ & \vdots & \vdots\end{bmatrix}$$

i.e. $T\Gamma=\{\Gamma,\Gamma^*\}$. Duplication transformation can be further divided into various types. After implementation of duplication transformation, the object is transformed to at least two objects, i.e. the original object and the duplicated object, or to multiple objects. According to the difference of duplicated objects, duplication transformation can be divided into:

Expansion duplication: $T\Gamma=\{\{\Gamma,\alpha\Gamma\},\alpha>1\}$

Contraction duplication: $T\Gamma=\{\{\Gamma,\alpha\Gamma\},0<\alpha<1\}$

Approximation duplication: $T\Gamma=\{\{\Gamma,\Gamma^*\},\Gamma\approx\Gamma^*\}$, wherein "≈" is approximate symbol.

Multiple duplication: $T\Gamma=\{\{\Gamma,\Gamma^*,\Gamma^*,\cdots,\Gamma^*\},\ \Gamma^*=\alpha\Gamma\}$

2.4.2 Nature of Extension Transformation

Extension transformation has the following basic natures:

(1) Existence of extension transformation

Suppose $\Gamma\in\{B, Co, k, U\}$, there must be an existing certain transformation *T*, to let $T\Gamma=\Gamma'$, and $\Gamma\neq\Gamma'$.

This nature shows that all matters, affairs, relations, criteria or universes of discourse in the world can be changed. Only solving contradictory problems complying with this nature, we can have flexible and alternative thinking to obtain various ideas to solve the contradictory problems.

(2) Conductivity of extension transformation

Suppose Γ_1, $\Gamma_2 \in \{B, Co, k, U\}$, if there is a certain transformation φ, when $\varphi\Gamma_1 = \Gamma_1'$, there is another transformation T to let $T\Gamma_2 = \Gamma_2'$, here T is referred to as conductive transformation caused by transformation φ. To distinguish it from common transformations, T is generally denoted as T_φ, and the relation between φ and T_φ is denoted as $\varphi \Rightarrow T_\varphi$.

Because there is a network of relations between matters, the transformation φ of Γ_1 will inevitably cause certain conductive transformations T_φ of its relevant object Γ_2. This nature shows that, before implementation of any transformation, the conductive transformation caused by the said transformation should be taken into full consideration, and in case the conductive transformation may generate negative effect, it should be considered whether it's necessary to implement the original transformation. If it's necessary, remedial measures for the generation of negative effect should be studied.

For example, increased waged will inevitably cause an improvement in social purchase power, and consequently drive domestic internal demand, so this kind of conductive effect is positive. For short-term benefit, some enterprises expand production that pollutes the environment, worsening the surroundings, for which a large amount of compensation must be paid, so this kind of transformation with loss outweighing the gain results in a negative conductive effect.

(3) Non-uniqueness of extension transformation

Suppose $\Gamma \in \{B, Co, k, U\}$, if there is a certain transformation T to let $T\Gamma = \Gamma'$, there should be another transformation T_1 to let $T_1\Gamma = \Gamma'$.

This nature shows that the transformation from Γ to Γ' can be realized by adopting various transformation methods. Exactly because of the non-uniqueness of extension transformation, we can have optional approaches to solve a contradictory problem.

(4) Composability of extension transformation

Many contradictory problems are hardly solved by using one basic transformation, but generally solved by using multiple transformations simultaneously, or successively. These transformations are composed of several basic transformations, and this nature of extension transformation is referred to as the composability of extension transformation.

2.4.3 Basic Operation of Extension Transformation

Transformation is the measure and tool for solving contradictory problems. It's obvious that transformation is capable of composition. When solving a problem, sometimes the objective cannot be realized by using one transformation, but be realized by composition of transformations. Composition of transformation is exactly the composition of transformation of method, creation, rules or universe of discourse, etc. for solving contradictory problems.

There are four types of basic operation for transformation, and their definitions are given as follows:

Suppose transformation object Γ_0, Γ_1, $\Gamma_2 \in \{B, k, U\}$, i.e. Γ_0, Γ_1, Γ_2 can be a basic-element, dependent criterion or universe of discourse.

Definition 2.15 (INTEGRAL transformation) if there are transformations T_1 and T_2 to let $T_1\Gamma_0 = \Gamma_1$, $T_2\Gamma_1 = \Gamma_2$, then

$$T\Gamma_0 = T_2(T_1\Gamma_0) = T_2\Gamma_1 = \Gamma_2$$

and the transformation $T=T_2T_1$ in the above equation is referred to as the integral of transformations T_1 and T_2. INTEGRAL transformation is the transformation to achieve objective about certain objects by two or more successive transformations.

When solving a problem, INTEGRAL transformation is generally used in the situation where the transformation from Γ_0 to Γ_2 is intended and cannot be directly realized, but can be realized if two transformations T_1 and T_2 are founded with T_1 transforms Γ_0 to Γ_1 and T_2 transforms Γ_1 to Γ_2. When applying INTEGRAL transformation, it must be noted that transformations T_1 and T_2 are sequential in order.

Definition 2.16 (AND transformation) If there are transformations T_1 and T_2 to let $T_1\Gamma_0=\Gamma_1$, $T_2\Gamma_0=\Gamma_2$, and $\Gamma_1\wedge\Gamma_2=\Gamma'_0$, then

$$T\Gamma_0= T_1\Gamma_0\wedge T_2\Gamma_0=\Gamma_1\wedge\Gamma_2=\Gamma'_0$$

and the transformation $T= T_1\wedge T_2$ in the above equation is referred to as AND transformation of transformations T_1 and T_2. AND transformation is the transformation to achieve the objective about certain object by simultaneously implementing two or more transformations. For example, in order to transform graphite to diamond, it must be simultaneously applied with pressure of 1125 kbar and high temperature of 3000℃, neither of the two can be dispensed.

[Example 2.9] In order to open certain local rural markets, in other words, to transform certain local farmers to customers, an electric enterprise simultaneously implemented the following transformations:

T_1: reducing product functions, i.e.

$$T_1\text{ (product A, types of function, 5) = (product A, types of function, 2)}$$

T_2: reducing product price, i.e.

$$T_2\text{ (product A, price, 3000 yuan) = (product A, price, 1700 yuan)}$$

T_3: providing home-delivery service, i.e.

T_3 (product A, delivery mode, transport by customer) = (product A, delivery mode, home-delivery by enterprise)

By implementing transformation $T= T_1 \wedge T_2 \wedge T_3$, let

$$T\begin{bmatrix} \text{product } A & \text{types of function} & 5 \\ & \text{price} & 3000\text{ Yuan} \\ & \text{delivery mode} & \text{transport by customer} \end{bmatrix}=\begin{bmatrix} \text{product } A & \text{types of function} & 2 \\ & \text{price} & 1700\text{ Yuan} \\ & \text{delivery mode} & \text{home-delivery by enterprise} \end{bmatrix}$$

the purchase intention of rural customers is greatly improved, and the local rural market is successfully opened.

Definition 2.17 (OR transformation) If there is a transformations T_1 and T_2 to let $T_1\Gamma_0=\Gamma'_0$, $T_2\Gamma_0=\Gamma'_0$, then

$$T\Gamma_0= T_1\Gamma_0\vee T_2\Gamma_0=\Gamma'_0$$

and the transformation $T= T_1\vee T_2$ in the above equation is referred to as OR transformation of transformations T_1 and T_2. OR transformation is the transformation to achieve the objective about certain objects by implementing transformation T_1 or transformation T_2.

Definition 2.18 (REVERSE transformation) If there is a transformation T' to let $T'\Gamma_1=\Gamma_0$ and $TT'=e$, then

$$T\Gamma_0=T(T'\Gamma_1)=e\Gamma_1=\Gamma_1$$

The transformation T' is referred to as the REVERSE transformation of transformation T, denoted as $T^{1}=T'$. The REVERSE transformation is the transformation implemented to restore the transformed object to the original object. The REVERSE transformation is a mode of reverse thinking of human kind, and will be introduced in detail afterwards.

The above-mentioned are relatively simple operations of transformation. In the process of actual problem solving, more complicated operations are generally required, i.e. composition transformation of the above basic operations, such as mid transformation and complementation transformation, etc. which are not introduced herein, but will be introduced as required.

2.4.4 Conductive Transformation

Because of the correlation between matters/affairs, the transformation of certain matter/affair, characteristic, measure, matter-element, affair-element or relation-element usually lead to transformations of a series of matter/affair, characteristic, measure, matter-element, affair-element or relation-element, and this kind of conductive transformation is an apt description of “moving the whole body by pulling one hair”.

In strategic planning, many enterprises adopt the “strategy of price reduction” to participate in market competitions, while the transformation of reducing product price will lead to the transformation of many other market factors, and some of the results of these conductive transformations are advantageous to the enterprise, but some are not, for example, the advantageous conductive transformations include: improvement of the enterprise’s market share, expansion of product sales volume, promotion of the enterprises expansion of production scale, raising of industrial entry threshold, and elimination of potential competitors; the disadvantageous conductive transformations include: reduction of industrial average profit, industrial profit loss, improvement of consumer’s price sensitivity, difficulty for consumers to form brand loyalty; damage to enterprise image, snaring the enterprise in “price trap”. Therefore, emphasis must be laid on analysis and application of conductive transformation to distinguish its advantages and disadvantages, and go after the former and avoid the latter.

In the conduction of contradictory problems, one type of problem that is commonly met is that in the situation the original contradictory problem P has been solved, a series of new contradictory problems are formed because of a generation of a series of conductive transformations, which is referred to as a conduction of contradictory problem. Some conductions of contradictory problems will finally cause failure to realize the original objective, i.e. generate new contradictory problems in the new situation for realization of the original objective.

During the process of treating contradictory problems, the generation of conduction of contradictory problems is usually inevitable. Hence, study on conduction of contradictory problems by formalized methods will help the study on computer-aid treatment of complicated contradictory problems.

1. General Definition of Conductive Transformation

Implicative relation of extension transformation and concept of conductive transformation are first introduced as follows.

Definition 2.19 (implicative relation of extension transformation) let $W=\{\Gamma\mid\Gamma\in\{B,Co,k,U\}\}$, $\boldsymbol{T}$ is the set of extension transformations on W, i.e. $\boldsymbol{T}=\{T\mid T:W\to P(W)\}$. As to $\Gamma_1,\Gamma_2\in W,\Gamma_1',\Gamma_2'\in P(W)$ and transformation $T_1,T_2\in\boldsymbol{T}$, if when $T_1\Gamma_1=\Gamma_1'$, there must be $T_2\Gamma_2=\Gamma_2'$, then it is called the transformation T_1 (about Γ_1) implicating transformation T_2 (about Γ_2), denoted as $T_1\Rightarrow T_2$ or $T_{\Gamma_1}\Rightarrow_{\Gamma_1}T_{\Gamma_2}$.

For easy expression, the transformation $T\Gamma=\Gamma'$ is sometimes denoted as $T=(\Gamma,\Gamma')$.

Definition 2.20 (first-order conductive transformation) let $W=\{\Gamma\mid\Gamma\in\{B,Co,k,U\}\}$, $\boldsymbol{T}$ is the set of extension transformations on W, i.e. $\boldsymbol{T}=\{T\mid T:W\to P(W)\}$. As to $\Gamma_0\in W,\varphi\in\boldsymbol{T}$, $\varphi=(\Gamma_0,\Gamma_0')$, if there is $\varphi_1\in\boldsymbol{T}$, $\Gamma\in W$, $\varphi_1=(\Gamma,\Gamma')$ to let $\varphi\Rightarrow\varphi_1$, then we call φ_1 first-order conductive transformation of φ, referred to as conductive transformation for short, denoted as T_φ. Now we have $T_\varphi\Gamma=\Gamma'$, and we call φ active transformation. The first-order conductive transformation of φ as a whole is denoted as $\{T_\varphi\}=\{T\mid T\Leftarrow\varphi\}$.

In order to give prominence to the relation between basic-elements and basic-elements in conductive transformation, the above defined first-order conductive transformation is also denoted as $T_\varphi(\Gamma_0,\Gamma)$, and

$$T_\varphi(\Gamma_0,\Gamma_i)=\{T_i\mid\varphi=(\Gamma_0,\Gamma_0'),T_i=(\Gamma_i,\Gamma_i'),\varphi\Rightarrow T_i,i=1,2,\cdots,m\}$$

is referred to as the set of conductive transformations of φ about Γ_0.

Definition 2.21 (n-times conductive transformation) let $W=\{\Gamma\mid\Gamma\in\{B,C_o,k,U\}\}$, $\boldsymbol{T}$ is the set of extension transformations on W, i.e. $\boldsymbol{T}=\{T\mid T:W\to P(W)\}$. As to $\Gamma_0\in W$, $\varphi\in\boldsymbol{T}$, if there is Γ_1, Γ_2, …, $\Gamma_n\in W$ and $\Gamma_0\tilde{\to}\Gamma_1\tilde{\to}\Gamma_2\tilde{\to}\cdots\tilde{\to}\Gamma_n$, then there must be $T_i\in\boldsymbol{T}$ to let $\varphi\Rightarrow T_1\Rightarrow T_2\Rightarrow\ldots\Rightarrow T_{n-1}\Rightarrow T_n$, wherein $\varphi=(\Gamma_0,\Gamma_0'),T_i=(\Gamma_i,\Gamma_i')(i=1,2,\cdots,n)$, then T_i is referred to as i-times conductive transformation of φ about Γ_i, denoted as ${}_{i-1}T_i$. The n-times conductive transformation of φ about Γ_n is ${}_{n-1}T_n$.

It's obvious that n-times conductive transformation has the following implicative relation of transformation:

$$\varphi\Rightarrow{}_0T_1\Rightarrow{}_1T_2\Rightarrow\ldots\Rightarrow{}_{n-2}T_{n-1}\Rightarrow{}_{n-1}T_n$$

Definition 2.22 (m-order transformation and m-order conductive transformation) suppose n-times conductive transformation $\varphi \Rightarrow {}_{\mathbf{0}}T_{\mathbf{1}} \Rightarrow {}_{\mathbf{1}}T_{\mathbf{2}} \Rightarrow \ldots \Rightarrow {}_{n-\mathbf{2}}T_{n-\mathbf{1}} \Rightarrow {}_{n-\mathbf{1}}T_n$, and ${}_{n-\mathbf{1}}T_n$ =(Γ_n, Γ_n'), $\Gamma_n \sim \Gamma'_{\mathbf{0}}$. Denote ${}_{n-\mathbf{1}}T_n = \psi$, then $\psi \Rightarrow {}_{\psi}T_{\mathbf{0}} = (\Gamma'_{\mathbf{0}}, \Gamma''_{\mathbf{0}})$, ${}_{\psi}T_{\mathbf{0}}$ is referred to as the second-order transformation of Γ_0, denoted as ${}_{\psi}T_{\mathbf{0}} = \varphi^{(2)}$. Now $\varphi^{(\mathbf{2})} = (\Gamma'_{\mathbf{0}}, \Gamma''_{\mathbf{0}})$.

Or if $\Gamma''_{\mathbf{0}} \sim \Gamma'_{\mathbf{1}}$, then there must be conductive transformation $T'_\varphi \in \boldsymbol{T}$ to let $\varphi^{(2)} \Rightarrow T'_\varphi$, $T'_\varphi = (\Gamma'_1, \Gamma''_1)$. The conductive transformation T_φ' is referred to as the second-order one-time conductive transformation of Γ_1 about φ, denoted as $T^{(1)}_{\varphi^{(2)}}$.

Similarly, if m-1-order transformation of Γ_0 is $\varphi^{(m-1)}$ (m>1), $\varphi^{(m-1)} \Rightarrow T_{\varphi^{(m-1)}}$, $T_{\varphi^{(m-1)}} = ({\Gamma_1}^{(m-2)}, {\Gamma_1}^{(m-1)})$, while $T_{\varphi^{(m-1)}} \Rightarrow T$ to let $T = ({\Gamma_0}^{(m-1)}, {\Gamma_0}^{(m)})$, then T is referred to as the m-order transformation of Γ_0, denoted as $T = \varphi^{(m)}$.

If $\varphi^{(m)} \Rightarrow \psi$ to let $\psi = ({\Gamma_i}^{(m-1)}, {\Gamma_i}^{(m)})$, then ψ is referred to as m-order i-times conductive transformation of Γ_i, denoted as $\psi = T^{(i)}_{\varphi^{(m)}}$.

[Example 2.10] suppose $B_{10} = (\text{food } O_1,\ \text{price},\ 2.0\ \text{Yuan/kg})$, and if

$$T_1 B_{10} = (\text{food } O_1, \text{ price}, \ 2.5 \text{ Yuan/kg}) = B_{10}{}',$$

according to relevant analysis, we have the following relevant basic-element:

$$B_1 = (\text{food } O_1, \text{ price}, \ v_1 \text{ Yuan/kg}) \sim B_2 = \begin{bmatrix} \text{food product } O_2, & \text{raw material}, & \text{food } O_1 \\ & \text{price}, & v_2 \text{ Yuan/kg} \end{bmatrix}$$

and there must be functional relation $v_2 = f(v_1)$. If

$$B_{20} = \begin{bmatrix} \text{food product } O_2, & \text{raw material}, & \text{food } O_1 \\ & \text{price}, & 4.0 \text{ Yuan/kg} \end{bmatrix}$$

According to conductive transformation, there must be transformation ${}_1T_2$, to let

$${}_1T_2 B_{20} = \begin{bmatrix} \text{food product } O_2, & \text{raw material}, & \text{food } O_1 \\ & \text{price}, & 5.0 \text{ Yuan/kg} \end{bmatrix} = B'_{20}$$

and because of correlation:

$$B_2 = \begin{bmatrix} \text{food product } O_2, & \text{raw material,} & \text{food } O_1 \\ & \text{price,} & v_2 \text{ Yuan/kg} \end{bmatrix}$$

$$\sim \quad B_3 = \begin{bmatrix} \text{worker } O_3, & \text{industry,} & \text{every industry} \\ & \text{wage,} & v_3 \text{ Yuan/month} \end{bmatrix}$$

$$\sim \begin{cases} B_4 = \begin{bmatrix} \text{fertilizer } O_4, & \text{purpose,} & \text{to plant crops } O_1 \\ & \text{price,} & v_4 \text{ Yuan/kg} \end{bmatrix} \\ B_5 = \begin{bmatrix} \text{transport vehicle } O_5, & \text{purpose,} & \text{to transport food } O_1 \\ & \text{transport charges,} & v_5 \text{ Yuan/km} \end{bmatrix} \end{cases}$$

i.e. $B_2 \sim B_3 \sim \begin{cases} B_4 \\ B_5 \end{cases}$.

According to conductive transformation, there must be transformations ${}_2T_3$ and ${}_2T_i, i = 4, 5$, to let

$${}_2T_3 B_{30} = B'_{30}, {}_3T_i B_{i0} = B_{i0}{}', i = 4, 5$$

i.e. the price raising of subsidiary food with food O_1 as raw material will cause increase of labor cost, price raising of fertilizer and transport charges, etc.

And because of the existing correlation:

$$\left.\begin{matrix} B_4 \\ B_5 \end{matrix}\right\} \sim B_1,$$

Then AND transformation ${}_3T_4 \wedge {}_3T_5$ will also cause conductive transformation of B_1, consequently leading to the rise in food prices and products. This is second-order conductive transformation.

An n-order conductive transformation is a formalized expression of the commonly referred "benign cycle" or "vicious cycle".

2. Conductive Effect

Conductive effect, as a vital indicator for quantitative study on conductive transformations and can be discussed by appropriate angles selected according to requirements. The following is the calculation methods for first-order conductive effect, *n*-times conductive effect and *m*-order conductive effect taking basic-elements as an example.

(1) First-order conductive effect about evaluated characteristic *c*

Given basic-elements B_0 and B, c is certain evaluated characteristic of basic-element, $B_0 \sim B$, if there is active transformation $\varphi=(B_0, B_0')$, and $\{T_\varphi\}$is the set of conductive transformations of φ,

$T_\varphi \in \{T_\varphi\}$is a transformation of $B: T_\varphi =(B,\ B')$,then $c(B') - c(B)$ is referred to as the first-order conductive effect of φ about characteristic c on the basic-element B, denoted as $c(T_\varphi) = c(B') - c(B)$, and $c(\varphi) = c(B_0') - c(B_0)$ is referred to as the active variable of φ about c.

If $c(T_\varphi) > 0,$ then this effect is referred to as the positive conductive effect about characteristic c; otherwise, if $c(T_\varphi) < 0,$ then this effect is the negative conductive effect about characteristic c; if $c(T_\varphi) = 0,$ then it's considered this conductive transformation has no conductive effect on characteristic c.

If $B_0 \sim \overset{n}{\underset{i=1}{\wedge}} B_i$, as to all ${}_\varphi T_i =(B_i,\ B_i')$, $i = 1, 2, \cdots, n,$ $c({}_\varphi T_i) = c(B_i') - c(B_i)$,

$$c(T_\varphi^{(1)}) = \sum_{i=1}^{n} c({}_\varphi T_i) = \sum_{i=1}^{n} [c(B_i') - c(B_i)]$$

is referred to as the first-order conductive effect of φ about the evaluated characteristic c.

(2) *n*-times conductive effect about the evaluated characteristic *c*

Given basic-element $B_0 \in W$, $\varphi \in \boldsymbol{T}$, if there are B_1, B_2 , …, $B_n \in W$, and $\mathbf{B_0} \tilde{\rightarrow} B_1 \tilde{\rightarrow} \mathbf{B_2} \tilde{\rightarrow} \cdots \tilde{\rightarrow} B_n$, then we have

$$\varphi \Rightarrow {}_\varphi T_{\mathbf{1}} \Rightarrow {}_{\mathbf{1}}T_{\mathbf{2}} \Rightarrow \ldots \Rightarrow {}_{n-\mathbf{2}}T_{n-\mathbf{1}} \Rightarrow {}_{n-\mathbf{1}}T_n$$

About certain evaluated characteristic c, the first-order first-time conductive effect of φ about c on the basic-element B_o is

$$c({}_\varphi T_1) = c(B_1') - c(B_1),$$

Denote ${}_\varphi T_1 \overset{\Delta}{=} {}_0 T_1$, then the first-order n-times conductive effect of φ about c on the basic-element B_o is

$$c^{(n)}(T_\varphi^{(1)}) \overset{\Delta}{=} \sum_{i=1}^{n} c({}_{i-1}T_i) = \sum_{i=1}^{n} [c(B_i') - c(B_i)]$$

The first-order conductive effect generated by transformation φ is an important effect, which shows that the functions exerted by transformation φ do not only include the direct function of φ=(B, B'), but also other complicated conductive functions of $c(T_\varphi^{(1)})$ or $c^{(n)}(T_\varphi^{(1)})$, etc., as well as conductive functions on all relevant basic-elements, which is a formalized expression of "moving the whole body by pulling one hair".

Here the first-order n-times conductive effect is only pertinent to $\mathbf{B_0} \tilde{\rightarrow} B_1 \tilde{\rightarrow} \mathbf{B_2} \tilde{\rightarrow} \cdots \tilde{\rightarrow} B_n$, but if

$B_0 \sim \bigwedge_{i=1}^{n} B_i$, and each $B_i(i=\mathbf{1},\mathbf{2},\cdots,n)$ is correlated to multiple basic-elements, its first-order n-times conductive effect will be more complicated, which can be further studied by readers who are interested in.

(3) *m*-order conductive effect about the evaluated characteristic *c*

Given basic-elements B_0 and B, c is certain evaluated characteristic of basic-element, B_0~B, active transformation φ=(B_0, $B_0^{'}$), $\varphi^{(m)} = (B_0^{(m-1)}, B_0^{(m)})$ is m-order transformation of B_0, $T_{\varphi^{(m)}} = (B^{(m-1)}, B^{(m)})$ is m-order conductive transformation of B_0, then the m-order conductive effect about the evaluated characteristic c is

$$c(T_{\varphi^{(m)}}) = c\,(B^{(m)}) - c\,(B^{(m-1)})$$

If $B_0 \sim \bigwedge_{i=1}^{n} B_i$ or $B_{\mathbf{0}} \tilde{\rightarrow} B_1 \tilde{\rightarrow} B_{\mathbf{2}} \tilde{\rightarrow} \cdots \tilde{\rightarrow} B_n$, then the m-order transformation of B_0 will be concluded in a similar matter of m-order conductive effect about the evaluated characteristic c, but more complicated, however, which is not described in detail herein.

3. Implicative System of Extension Transformation

The change of certain basic-elements caused by the nature of correlation and correlative network will lead to the change of other basic-elements related to it, and this kind of change is mutually transmitted in a correlative network. Therefore, an implicative system about transformation can be generated according to the correlative network and the conductive transformation between basic-elements therein.

In general, as to basic-elements B_0, suppose B~B_0, then we have $T_B \Rightarrow {}_{B}T_{B_0}$ or $T_{B_0} \Rightarrow {}_{B_0}T_B$, wherein, T_B indicates active transformation of basic-element B, and ${}_{B}T_{B_0}$ indicates the conductive transformation of B_0 caused by the transformation of B; T_{B_0} indicates active transformation of B_0, and ${}_{B_0}T_B$ indicates the conductive transformation of B caused by the transformation of B_0.

The implicative relation of transformation can be in the following situations:

① As to basic-elements B and B_1, …, B_m, if $B \sim \bigwedge_{i=1}^{m} B_i$, then

$$T_B \Rightarrow \bigwedge_{i=1}^{m} {}_{B}T_{B_i} \quad \text{or} \quad \bigwedge_{i=1}^{m} T_{B_i} \Rightarrow \bigwedge_{i=1}^{m} {}_{B_i}T_B$$

② As to basic-elements B and B_1, …, B_m, if $B \sim \bigvee_{i=1}^{m} B_i$, then

$$T_B \Rightarrow \bigvee_{i=1}^{m} {}_{B}T_{B_i} \quad \text{or} \quad \bigvee_{i=1}^{m} T_{B_i} \Rightarrow \bigvee_{i=1}^{m} {}_{B_i}T_B$$

③ As to basic-elements B and B_1, …, B_m, if

$$\bigvee_{i=1}^{m} B_i \tilde{\rightarrow} B,$$

then the generated implicative system of transformation: $\bigvee_{i=1}^{m} T_{B_i} \Rightarrow \bigvee_{i=1}^{m} {}_{B_i}T_B$.

④ As to basic-element B and B_1, …, B_m, if

$$\bigwedge_{i=1}^{m} B_i \tilde{\rightarrow} B,$$

then the generated implicative system of transformation: $\bigwedge_{i=1}^{m} T_{B_i} \Rightarrow \bigwedge_{i=1}^{m} {}_{B_i}T_B$.

⑤ As to basic-elements B and B_1, …, B_m, if

$$B \tilde{\rightarrow} \bigvee_{i=1}^{m} B_i,$$

then the generated implicative system of transformation: $T_B \Rightarrow \bigvee_{i=1}^{m} {}_{B}T_{B_i}$.

⑥ As to basic-elements B and B_1, …, B_m, if

$$B \tilde{\rightarrow} \bigwedge_{i=1}^{m} B_i,$$

then the generated implicative system of transformation: $T_B \Rightarrow \bigwedge_{i=1}^{m} {}_{B}T_{B_i}$.

2.4.5 Types of Extension Transformation

According to the types of transformation objects, extension transformations can be divided into transformation of element in the universe of discourse, transformation of dependent criterion, and transformation of universe of discourse. The element in universe of discourse can be basic-element, compound-element or certain key element in them, so the transformations of element can be further divided into transformation of basic-element and transformation of compound-element. The transformation of compound-element is similar to the transformation of basic-element, but more complicated, which will not be introduced herein.

1. Transformation of Basic-Element

The transformation of a basic-element refers to the transformation of basic-element B in the universe of discourse U. When B is matter-element M, the transformation T_B is transformation of matter-element, i.e. $T_B=T_M$; when B is affair-element A, the transformation T_B is transformation of affair-element $T_B=T_A$; when B is relation-element R, the transformation T_B is transformation of relation-element $T_B=T_R$.

(1) Transformation of element in basic-element and conductive transformation between elements

Because basic-element B is a triple composed of object, characteristic and corresponding measure, the transformation of basic-element can be further divided into transformation of O, transformation of c, and transformation of v, usually denoted as $T=(T_O,T_c,T_v)$ and T_O,T_c,T_v are referred to as the transformation of an element in basic-element.

Transformation of basic-element $B=(O,c,v)$ can be in the following situations:

a) If $T_O O=O'$ is active transformation, $T_c c=c$, $T_v v=v$, i.e. both T_c, T_v are unitary transformations, then

$$_O T_B B=(T_O O, c, {}_O T_v v)=(O', c, v')$$

wherein $_O T_v$ is conductive transformation of measure caused by the active transformation of object *O*.

In particular, if $_O T_v=e$, i.e., $_O T_v v=v$, then

$$_O T_B B=(T_O O, c, {}_O T_v v)=(O', c, v)$$

b) If $T_c c=c'$ is active transformation, $T_O O=O$, $T_v v=v$, i.e. both T_O, T_v are unitary transformations, then

$$_c T_B B=(O, T_c c, {}_c T_v v)=(O, c', v')$$

wherein $_c T_v$ is conductive transformation of measure caused by the active transformation of characteristic *c*.

c) If $T_v v=v'$ is active transformation, $T_O O=O$, $T_c c=c$, i.e. both T_O, T_c are unitary transformations, then

$$_v T_B B=({}_v T_O O, c, T_v v)=(O', c, v')$$

wherein $_v T_O$ is the conductive transformation of object caused by the active transformation of measure *v*.

d) If all $T_O O=O'$, $T_c c=c'$ and $T_v v=v'$ are active transformations without conductive transformation between them, it's denoted as

$$T_B B=(T_O O, T_c c, T_v v)=(O', c', v')=B'$$

(2) Basic transformations of basic-element

Basic transformations of basic-element include substitution transformation, increasing/decreasing transformation, expansion/contraction transformation, decomposition transformation, and duplication transformation.

a) Substitution transformation

As to basic-element $B_0(t)$=($O(t)$, c, v (t)), if there is certain transformation T that transforms $B_0(t)$ to $B(t)$=(O (t), c, v (t)), i.e. $T B_0(t)= B(t)$, then the transformation T is referred to as substitution transformation of basic-element $B_0(t)$.

For easy writing, basic-element is not written in the form of dynamic basic-element in the situation without causing confusion hereinafter, for example, B_0=(fireproof board A, function, fireproof), we make TB_0=(fireproof paper B, function, fireproof)=B, then T is substitution transformation of the object of basic-element B_0.

b) Increasing/decreasing transformation

Increasing transformation: as to basic-element B_0= (O_0, c_0, v_0), B= (O, c, v) is the increasable basic-element of B_0, if there is certain transformation T, to let

$$TB_0=B_0\oplus B$$

then T is referred to as the increasing transformation of basic-element B_0.

For example, as to matter-elements M_0= (table A_1, height, 0.8m), M= (chair A_2, height, 0.5m), M is increasable matter-element of M_0, we make $TM_0=M_0\oplus M$= (table $A_1\oplus$chair A_2, height, 1.3m), then T is increasing transformation of M_0.

Decreasing transformation: as to basic-element B_0=(O_0, c_0, v_0), B=(O, c, v) is the basic-element obtained after decomposition of B_0, if there is certain transformation T, to let

$$TB_0=B_0\Theta B$$

then T is referred to as the decreasing transformation of basic-element B_0.

For example: as to matter-elements M_0= (product A, weight, $a_1\oplus a_2$), M= (component B, weight, a_1), M_0//{ M, M_1}, we make $TM_0=M_0\Theta M$= (product A', weight, a_2) $=M_1$, then T is decreasing transformation of M_0.

In the production process, the reduction of redundant action or work procedures belongs to the decreasing transformation of affair-element, which can significantly improve production efficiency.

c) Expansion/contraction transformation

Expansion transformation: if $TB_0=\alpha B_0$ ($\alpha>1$), then we call T expansion transformation of B_0. Quantitative expansion transformation is multiple quantitative expansion of basic-element, for example, making cartoon characters in a TV program in the size of a real person to give performance among assemblies to attract children.

As for matter-element, its quantitative expansion transformation will inevitably lead to expansion transformation of the matter, for example, the volume expansion of a balloon will inevitably lead to expansion of the balloon itself.

Contraction transformation: if $TB_0=\alpha B_0$ $(0<\alpha<1)$, then we call T contraction transformation of B_0.

As for matter-element, its quantitative contraction transformation will inevitably lead to contraction transformation of the matter.

d) Decomposition transformation

As to basic-element B_0= (O_0, c_0, v_0), if $B_0=B_1\oplus B_2\oplus\ldots\oplus B_n$, and there is a transformation T, to let

$$TB_0=\{B_1, B_2, \ldots, B_n\}$$

then we call T decomposition transformation of basic-element B_0.

For example, on the second-hand market, the old machinery equipment is usually decomposed into units according to their functions for sale in many shops, which usually result in more profits than sale of complete machine. The production procedure can be decomposed for flow operations, in which different workers should complete different actions.

e) Duplication transformation

If $TB_0=\{B_0, B^*_0\}$, then we call T duplication transformation of basic-element B_0.

Duplication transformation is the transformation that duplicates the basic-element to multiple basic-elements, such as photo processing and copying, etc.

2. Transformation of Dependent Criterion

Dependent criterion is a kind of rule on contradiction, non-contradiction or contradictory degree of a problem, by which to let certain elements fail to meet limitation, consequently causing "unknowable" and "unfeasible" situations. When dependent criterion is changed, certain elements that fail to meet the original limitation can be transformed to elements that meet "new limitations", thus to transform the unfeasible to feasible, negative to positive, and unknowable to knowable.

In many practical works, the change of dependent criterion is an approach to solve problems, for example, certain contradictory problems that are limited in planned economy become non-contradictory under the rules of market economy. For policy making, different policies should be used in different periods, and different rules should be implemented in different regions; in market competitions, the game rule is changing; in construction engineering, different safety coefficients are adopted in different geological environments; in electromechanical products, the rated current and voltage are various, all of which belong to transformation of dependent criteria. The background of transformation of dependent criterion is exactly these practical problems.

For example, the house with the price of 300,000 yuan—800,000 yuan is not affordable for persons with an income of 3000-5000 yuan/month, but they can be transformed from non-customers to customers by instalments, paying over 2000 yuan each month for 15 years, apart from the down payment.

Dependent criterion k also has the five basic transformations mentioned above:

$$Tk = k'$$

$$Tk = k \oplus k_1$$

$$Tk = k \ominus k_1$$

$$Tk = \alpha k$$

$$Tk = \{k_1, k_2, ..., k_n\}$$

$$Tk = \{k, k^*\}$$

3. Transformation of Universe of Discourse

We refer to whole study objects as universe of discourse and that is a set.

In classical logic and fuzzy logic, universe of discourse is fixed without change, which reflects a habitual thinking of human beings: the objects involved by the problem are restricted in a certain range. It's advantageous for the study of a solution to a problem be found easily within a fixed range, which, however, limits our field of view. When treating contradictory problems in particular, an important method is to jump out the set of objects that is formed by habitual fields, such as talents of foreign language that have to be found in the department of foreign language, etc. In the objective world, a problem may be contradictory in certain ranges but not contradictory in another universe of discourse. Therefore, in Extenics, the universe of discourse is not fixed without change, but contradictory problems are studied to find ways to transform them to be reconcilable in the situation of transformation of the universe of discourse.

For example, in marketing, sellers are continuously expanding the marketing range from a region to a province, to the country and to the world, transforming non-customers to customers, and consequently expanding the market. When considering its own resources, an enterprise usually expands from its controllable resource to the resource of the local city, local province, the country, and even overseas. Therefore, the thinking that considers the universe of discourse is fixed without change usually obstructs our exploring activities. Transformation of the universe of discourse is abstracted exactly from these practical backgrounds.

According to extensible analysis of the universe of discourse, the universe of discourse has the following basic transformations:

(1) Substitution transformation: as to any one universe of discourse U, if there is another universe of discourse U' and transformation T, to let

$$TU=U'$$

then transformation T is referred to as a substitution transformation of universe of discourse U.

For example, the target market of a certain enterprise is in City A, then its universe of discourse U is the whole population in City A. Changing the target market to another city is the equivalent to substitution transformation of the universe of discourse.

(2) Increasing transformation: as to any one universe of discourse U, if there is another universe of discourse U_1 and transformation T, to let

$$TU=U\cup U_1$$

then transformation T is referred to as increasing transformation of universe of discourse U.

(3) Decreasing transformation: as to any one universe of discourse U, if there is another universe of discourse U_1 and transformation T, to let

$$TU=U_1, \quad U_1\subset U$$

then transformation T is referred to as decreasing transformation of universe of discourse U.

For example, the universe of discourse of certain enterprise's market U is the whole population in City A, when this universe of discourse cannot meet the requirement of the enterprise, increasing transformation of the universe of discourse can be adopted, for example, take U_1={whole population in City B}, and make $TU=U\cup U_1$, which is increasing transformation of universe of discourse; when the enterprise needs adjusting product structure to produce products used by certain special groups only, decreasing transformation of universe of discourse can also be adopted, for example, certain garment enterprise only produces school wear, then people other than students may not be considered in its universe of discourse, i.e. U_1={whole students in City A}, $U_1 \subset U$, while the whole universe of discourse *U* may not be necessarily considers.

(4) Quantitative expansion transformation: as to any one real number's universe of discourse *U*, if there is transformation *T* and real number α ($\alpha > 1$), to let

$$TU=\alpha U$$

then transformation *T* is referred to as quantitative expansion transformation of real number's universe of discourse *U*.

(5) Quantitative contraction transformation: as to any one real number's universe of discourse *U*, if there is transformation *T* and real number α ($0<\alpha<1$), to let

$$TU=\alpha U$$

then transformation *T* is referred to as quantitative contraction transformation of real number's universe of discourse *U*.

(6) Decomposition transformation: as to certain universe of discourse *U* if there is transformation *T*, to let

$$TU=\{U_1, U_2, \ldots, U_n\}, \text{ and } U_i \subset U \quad (i=1,2,\ldots,n)$$

then transformation *T* is referred to as decomposition transformation of universe of discourse *U*.

In summary, universe of discourse *U* also has five basic transformations:

$$TU=U'$$

$$TU=U \oplus U_1$$

$$TU=U \,\Theta\, U_1, \quad (U \supset U_1)$$

$$TU=\alpha U$$

$$TU=\{U_1, U_2, \ldots, U_n\}$$

$$TU=\{U, U^*\}$$

2.4.6 Transformation of Conjugate Part and Conjugate Transformation

1. Transformation of Conjugate Part

The so-called transformation of conjugate parts refers to the active transformation of any one part in the eight conjugate parts of matter. In terms of products, the transformations of shape, dimensions and materials are transformations of the product's real part; the transformations of brand name and brand popularity are transformations of the product's imaginary part; the transformations of product components is the transformations of the product's hard part; the transformations of product structure and connection mode of components are transformations of the product's soft part; the development of the latent function of the product's apparent part, such as to design the product's package to reusable form, is the transformation of its apparent part; the transformation of the product's part that is disadvantageous to consumers, such as to minimize the negative function of medicine on human body, and to manage to eliminate radiation of mobile phone, is the transformation of the product's negative part.

In general, in the case without considering the mid-part, matter O_m can be divided into four pairs of conjugate parts according to its physical property, systematic property, dynamic property and antithetic property, i.e. imaginary part im(O_m) and real part re(O_m); soft part sf(O_m) and hard part hr(O_m); latent part lt(O_m) and apparent part ap(O_m); negative part $\mathrm{ng}_c(O_m)$ and positive part $\mathrm{ps}_c(O_m)$. The transformations of certain parts of these eight parts are collectively referred to as transformation of conjugate part.

The pairs of transformation of the basic-element formed by every conjugate part are denoted as

$$\begin{aligned}
&T_{\mathrm{im}}M_{\mathrm{im}} = M'_{\mathrm{im}}, T_{\mathrm{re}}M_{\mathrm{re}} = M'_{\mathrm{re}},\\
&T_{\mathrm{sf}}M_{\mathrm{sf}} = M'_{\mathrm{sf}}, T_{\mathrm{hr}}M_{\mathrm{hr}} = M'_{\mathrm{hr}},\\
&T_{\mathrm{lt}}M_{\mathrm{lt}} = M'_{\mathrm{lt}}, T_{\mathrm{ap}}M_{\mathrm{ap}} = M'_{\mathrm{ap}},\\
&T_{\mathrm{ng_c}}M_{\mathrm{ng_c}} = M'_{\mathrm{ng_c}}, T_{\mathrm{ps_c}}M_{\mathrm{ps_c}} = M'_{\mathrm{ps_c}}
\end{aligned}$$

Study on the transformations of conjugate parts of matter is the basis for study on conjugate transformation. The mode of transformation of conjugate parts is the same to the mode of transformation of matter, including substitution transformation, increasing/decreasing transformation, expansion/contraction transformation, decomposition transformation, and operation of transformation, etc.

2. Conjugate Transformation

In 2.4.4 of this section, the basic knowledge on conductive transformation and conductive effect has been introduced, which will be the basis for the discussion of another special type of conductive transformation – conjugate transformation in this section.

The transformation of certain conjugate parts that lead to transformation of the other conjugate part in the same pair of conjugate parts is referred to as conjugate transformation.

Conjugate transformation can be divided into imaginary-real conjugate transformation, soft-hard conjugate transformation, latent-apparent conjugate transformation, and negative-positive conjugate transformation.

Principle 2.14 Transformation of the real part basic-element of matter will lead to the conductive transformation of the imaginary part basic-element that is related to it, while the transformation of the imaginary part basic-element of matter will also lead to conductive transformation of the real part basic-element that is related to it.

Suppose

$$M_{\mathrm{im}} = \begin{bmatrix} \mathrm{im}(O_m), & c_{i1}, & v_{i1} \\ & c_{i2}, & v_{i2} \\ & \vdots & \vdots \\ & c_{in}, & v_{in} \end{bmatrix}$$

$$M_{\mathrm{re}} = \begin{bmatrix} \mathrm{re}(O_m), & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \\ & \vdots & \vdots \\ & c_{rm}, & v_{rm} \end{bmatrix}$$

If $T_{\mathrm{im}} M_{\mathrm{im}} = M'_{\mathrm{im}}$, there must be ${}_{\mathrm{im}}T_{\mathrm{re}}$, $T_{\mathrm{im}} \Rightarrow {}_{\mathrm{im}}T_{\mathrm{re}}$, to let ${}_{\mathrm{im}}T_{\mathrm{re}} M_{\mathrm{re}} = M'_{\mathrm{re}}$, then ${}_{\mathrm{im}}T_{\mathrm{re}}$ is referred to as imaginary-real conjugate transformation of T_{im}. Similarly, ${}_{\mathrm{re}}T_{\mathrm{im}}$ is referred to as imaginary-real conjugate transformation of T_{re}.

Wherein T_{re} and T_{im} indicate respectively the active transformations of the real part basic-element M_{re} and imaginary part basic-element M_{im} of matter O_m, while ${}_{\mathrm{re}}T_{\mathrm{im}}$ and ${}_{\mathrm{im}}T_{\mathrm{re}}$ indicate respectively the conductive transformations of the imaginary part basic-element M_{im} and real part basic-element M_{re} of the matter.

For example, in terms of PC, the fittings, screen, sound, and all connecting wires of the computer are its real part. For normal working of the computer, when assembling the computer, all the fittings must be connected by the connecting wires through jacks and slots according to specifications, and the computer must be loaded with operation system and various applications. All physical parts of the computer are its real part, while its non-physical parts, such as the computer’s brand value, apparent image, popularity, reputation degree, operation system and various applications are its imaginary part. In order to change the imaginary part, such as to improve brand value, the enterprise must input enough manpower and material resources, and change the function and quality of hardware, or conduct extensive advertising and publicity. These transformations are imaginary-real conjugate transformations.

In the process of solving contradictory problems, imaginary-real conjugate transformations are commonly used, but the realization of imaginary-real conjugate transformations is not necessarily always advantageous for the enterprise, because the negative effect generated in conductive transformation between conjugate parts will obstruct the enterprise development. For example, certain enterprise inputs have huge funds in advertisement to improve their popularity. Although the popularity is immediately and significantly improved, excessive input in advertisement results in deficient input in production and product development. That’s to say the transformation of imaginary part leads to a decrease of enterprise strength, and finally results in a brief lasting of the enterprise’s reputation. Therefore, emphasis must be laid on the effect of this kind of conduction and effective measures must be taken to let the transformation become the driving force for enterprise development, to which special attention must be paid when solving contradictory problems.

Principle 2.15 Transformation of hard part basic-element of matter will lead to conductive transformation of the soft part basic-element that is related to it, while transformation of the soft part basic-element will also lead to a conductive transformation of the hard part basic-element that is related to it.

This kind of conductive transformation is referred to as soft-hard conjugate transformation, which can be expressed by symbols as

$$T_{\mathrm{hr}} \Rightarrow {}_{\mathrm{hr}}T_{\mathrm{sf}}\,,\ \ T_{\mathrm{sf}} \Rightarrow {}_{\mathrm{sf}}T_{\mathrm{hr}}$$

Wherein T_{hr} and T_{sf} indicate respectively the active transformations of hard part basic-element M_{hr} and soft part basic-element M_{sf} of matter O_m, while ${}_{\mathrm{hr}}T_{\mathrm{sf}}$ and ${}_{\mathrm{sf}}T_{\mathrm{hr}}$ indicate respectively the conductive transformations of soft part basic-element M_{sf} and hard part basic-element M_{hr} of matter O_m.

When composing department personnel (hard part), any organization should consider not only the post requirement for every personnel in the department, but also the coordination between the personnel (soft part). If the personnel in the department are intriguing against each other and undermining each other's work, even the greatest energy of every personnel cannot be exerted. If the personnel in the department are in harmonious relation and mutual coordination, powerful cohesion and creation will be generated. Therefore, the change of relations in the department (soft part) will lead to the change of everyone's function in the department (hard part). In addition, the change of external relations will also exert functions on the hard part.

When employing personnel, information not only on the applicant itself but on its previous work should be reviewed. The person who has previously done relevant work will be given priority at employment, because his relevant work experience will result in relevant relation net, and once employed, he will assume his post with all of his external relations (soft part) accompanying with him. It can be seen that the change of hard part will inevitably lead to the change of soft part.

In history, many weak countries were forced to establish "unequal treaty" with powerful countries, and make concessions in order to accommodate to a situation by "ceding land", this kind of practice to exchange "peace" by "ceding land" is exactly the method to obtain transformation of a soft part by utilizing the transformation of a hard part.

Principle 2.16 Transformation of a negative part basic-element of matter will lead to a conductive transformation of s positive part basic-element that is related to it, while the transformation of a positive part basic-element will lead to a conductive transformation of a negative part basic-element that is related to it.

This kind of conductive transformation is referred to as a negative-positive conjugate transformation, which can be expressed by symbols as

$$T_{\mathrm{ng}_c} \Rightarrow {}_{\mathrm{ng}_c}T_{\mathrm{ps}_c},\ T_{\mathrm{ps}_c} \Rightarrow {}_{\mathrm{ps}_c}T_{\mathrm{ng}_c}$$

Wherein T_{ng_c} and T_{ps_c} indicates respectively active transformations of a negative part basic-element M_{ng} and a positive part basic-element M_{ps} of matter O_m on characteristic c, while ${}_{\mathrm{ng}_c}T_{\mathrm{ps}_c}$ and ${}_{\mathrm{ps}_c}T_{\mathrm{ng}_c}$ indicate respectively conductive transformations of positive part basic-elements M_{ps} and negative part basic-elements M_{ng} of matter O_m about characteristic c by T_{ng_c} and T_{ps_c}.

After system reformation and the adjustment of production structure in a certain enterprise, the result is that partial workshops and equipment become redundant. In terms of profit, all of these redundant "workshops and equipment" become a negative part of the enterprise, because these workshops and equipment cannot be used to generate profit, but should be maintained by the enterprise at great cost. In order to change this situation, the enterprise has to prepare careful planning, to let these negative parts serve for the enterprise objectives. According to the principle of negative-positive conjugate transformation, the negative part can be transformed to a positive part through certain transformations, such as renting the workshops and equipment, etc.

Principle 2.17 Transformation of latent part basic-element of matter will lead to conductive transformation of the apparent part basic-element that is related to it, while transformation of apparent part basic-elements of matter will also lead to a conductive transformation of the latent part that is related to it.

This kind of conductive transformation is referred to as latent-apparent conjugate transformation, which can be expressed by symbols as

$$T_{\mathrm{lt}} \Rightarrow {}_{\mathrm{lt}}T_{\mathrm{ap}}, T_{\mathrm{ap}} \Rightarrow {}_{\mathrm{ap}}T_{\mathrm{lt}}$$

Wherein T_{lt} and T_{ap} indicate respectively the active transformations of latent part basic-element M_{lt} and apparent part basic-element M_{ap} of matter O_m, while ${}_{\mathrm{lt}}T_{\mathrm{ap}}$ and ${}_{\mathrm{ap}}T_{\mathrm{lt}}$ indicate respectively conductive transformations of apparent part basic-element M_{ap} and latent part basic-element M_{lt} of matter O_m by T_{lt} and T_{ap}.

Matter's latent parts include positive latent parts and negative latent parts, for example, the enterprise's "hidden trouble" and "crisis" lurking in the development process, etc. are negative latent parts of the enterprise, while the enterprise's "potential market", employees' "potential capacity", and enterprise's "development potential" are positive latent parts of an enterprise. Therefore, the way to adopt effective transformations is to let the enterprise's positive latent parts appear as soon as possible and let the enterprises negative latent parts remain hidden or appear as positive apparent parts is an extremely vital task of the enterprise.

An enterprise is usually beaten by its potential competitor, so the way to correctly discover its potential competitor is also the key to enterprise's success. In terms of Kodak, it's generally considered that the competitor of Kodak is Fuji, but actually the greatest threat faced by Kodak is the rapid development of the technology of family-owned cameras, i.e. the digital camera jointly developed by Canon and Sony.

Until now, we've introduced the conductive transformations between every pair of conjugate parts of matter, referred to as conjugate transformation. Special attention should be paid to the fact that the active transformation between the measures about certain characteristic in real part may lead to a conductive transformation of measures about multiple characteristics in the imaginary part, which is also applicable to other conjugate parts. If this nature is fully utilized, we can achieve many things in one stroke. Actually, other conductive transformations do exist inside a matter, for example, the transformation of certain parts in real parts will lead to the transformation of the other part that is related to it in the real part; the transformation of certain parts in imaginary parts will lead to the transformation of the other part that is related to it in the imaginary part; the transformation of the real part will lead to the transformation of the soft part, while the transformation of the imaginary part will lead to the transformation of the soft part; …all of which belongs to conductive transformation, however, are not described in details herein.

2.5 Compound Element

Problems in the real word are usually very complicated, which result from compositions and compounds of people, affairs and matters. Therefore, description of these objects should be expressed in the mode of compounds of matter-elements, affair-elements and relation-elements, which are collectively referred to as compound elements. The study on the constitution, operation and transformation of compound elements thus has become the basis for the study on complicated problems.

2.5.1 Forms of Compound Elements

There are many forms of Compound elements, but only the common ones are introduced herein.

1. Compound Elements Formed by Matter-elements and Matter-elements

If $M=(O_m, c_m, v_m)$,$M_1=(O_{m1},c_{m1},v_{m1})$, then $M'=(M_1, c_m, v_m)=((O_{m1},c_{m1},v_{m1}), c_m, v_m)$ is a compound element.

For example,

$$M_1=((\text{Equipment } A, \text{the owner, Company D}), \text{time}, <1999, 2003>)$$

indicates “Equipment A has been owned by Company D during 1999~2003”.

The characteristic to evaluate the matter-element is referred to as its evaluated characteristic, expressed by c_0, i.e. as to

$$M=(O_m, c_m, v_m),$$

it has corresponding compound element

$$M'=(M,c_0,c_0(M)),$$

in particular case, $c_m= c_0$, $v_m= c_0(M)$.

For example, if

$$M=(\text{person A, height, 1.7m}),$$

then it has a compound element

$$M'= (M, \text{touch height, 2.2m}).$$

For another example, M= (ship A, carrying tonnage, v_1 tons), it has the compound element on the characteristic of “draught”

$$M'= (M, \text{draught}, a),$$

while the carrying tonnage of ship A becomes v_2 tons, i.e.

$$M_1= (\text{ship } A, \text{carrying tonnage}, v_2 \text{ tons}),$$

now it has the compound element about the characteristic of “draught”

$$M_1' = (M_1, \text{draught}, b).$$

2. Compound Elements Formed by Matter-elements and Affair-elements

If $M=(O_m, c_m, v_m)$ and $A=(O_a, c_a, v_a)$, then both $A(M)=(O_a, c_a, M)$ and $M_v(A)=(O_m, c_m, A)$ and $M_O(A)=(A, c_m, v_m)$ are compound elements formed by matter-elements and affair-elements.

For example, $M=$ (elephant A, weight, $v$kg), $A=$ (weighing, dominating object, M), then

$$A= (\text{weighing, dominating object, (elephant } A\text{, weight, } v\text{kg)}).$$

For another example,

$$M_v(A)= (\text{electric lamp, function, (provide, dominating object, light energy)}),$$

$$M_O(A)= ((\text{wage, dominating object, war}), \text{cost, high}).$$

The characteristic to evaluate the affair-element is referred to as its evaluated characteristic, expressed by c_0, i.e. as to

$$A= (O_a, c_a, v_a)$$

it has a corresponding compound element

$$M'=(A, c_0, c_0(A)).$$

3. Compound Elements Formed by Matter-elements and Relation-elements

If $M_1=(O_{m1}, c_{m1}, v_{m1})$, $M_2=(O_{m2}, c_{m2}, v_{m2})$, $R=\begin{bmatrix} O_r, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \end{bmatrix}$, $M=(O_m, c_m, v_m)$, then

$$R=\begin{bmatrix} O_r, & c_{r1}, & M_1 \\ & c_{r2}, & M_2 \end{bmatrix}, M=(R, c_m, v_m)$$

is referred to as the compound element formed by matter-element and relation-element.

The characteristic to evaluate the relation-element is referred to as its evaluated characteristic, expressed by c_0, i.e. as to

$$R=\begin{bmatrix} O_r, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \end{bmatrix}$$

it has corresponding compound element

$$M'=(R, c_0, c_0(R)).$$

For example, suppose $M_1=$(person A, temperament, irritable), $M_2=$(person B, temperament, mild), when we have

$$R=\begin{bmatrix} \text{complementary relation}, & c_{r1}, & M_1 \\ & c_{r2}, & M_2 \end{bmatrix}$$

4. Compound Elements Formed by Affair-elements and Affair-elements

If $A=(O_a, c_a, v_a)$ and $A_1=(O_{a1}, c_{a1}, v_{a1})$, then $A=(O_a, c_a, (O_{a1}, c_{a1}, v_{a1}))$ is referred to as the compound element formed by an affair-element and an affair-element.

For example,

$$A=\begin{bmatrix} \text{agree}, & \text{dominating object}, & A_1 \\ & \text{acting object}, & \text{he} \end{bmatrix},$$

$$A_1=\begin{bmatrix} \text{participate}, & \text{receiving object}, & \text{dancing match} \\ & \text{acting object}, & \text{I} \end{bmatrix}$$

then A indicates "he agrees with my participating in the dancing match".

5. Compound Element Formed by Affair-elements and Relation-elements

If

$$A=(O_a, c_a, v_a),\ R=\begin{bmatrix} O_r, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \end{bmatrix}$$

Then $A=(O_a, c_a, R)$ is referred to as the compound element formed by the relation element and the affair-element.

Similarly, if $A_1=(O_{a1}, c_{a1}, v_{a1})$, $A_2=(O_{a2}, c_{a2}, v_{a2})$, $R=\begin{bmatrix} O_r, & c_{r1}, & v_{r1} \\ & c_{r2}, & v_{r2} \end{bmatrix}$, then

$$R=\begin{bmatrix} O_r, & c_{r1}, & A_1 \\ & c_{r2}, & A_2 \end{bmatrix}$$

is the compound element formed by the affair-element and the relation-element.

For example,

$$A=\left[\text{resume}, \quad \text{dominating object}, \quad \begin{bmatrix} \text{deplomatic relation}, & c_{r1}, & \text{country A} \\ & c_{r2}, & \text{country B} \end{bmatrix}\right]$$

6. Compound Element Formed by a Relation-element and a Relation-element

If

$$R_1=\begin{bmatrix} O_{r1}, & c_{r1}, & v_{r11} \\ & c_{r2}, & v_{r12} \end{bmatrix},\ R_2=\begin{bmatrix} O_{r2}, & c_{r1}, & v_{r21} \\ & c_{r2}, & v_{r22} \end{bmatrix}$$

then

$$R=\begin{bmatrix} O_r, & c_{r1}, & R_1 \\ & c_{r2}, & R_2 \end{bmatrix}$$

is referred to as the compound element compounded by relation-element R_1 and relation-element R_2.

For example,

$$R_1=\begin{bmatrix} \text{relation of loan}, & c_{r1}, & \text{company } \mathrm{D}_1 \\ & c_{r2}, & \text{bank } \mathrm{D}_2 \end{bmatrix},\ R_2=\begin{bmatrix} \text{relation of guarantee}, & c_{r1}, & \text{company } \mathrm{D}_3 \\ & c_{r2}, & \text{company } \mathrm{D}_1 \end{bmatrix}$$

then

$$R=\begin{bmatrix} \text{associative relation}, & c_{r1}, & R_1 \\ & c_{r2}, & R_2 \end{bmatrix}$$

is the compound element compounded by R_1 and R_2.

2.5.2 Extensible Analysis of Compound Elements

A compound element also has the extension similar to that of a basic-element, including divergence, correlation, implication and extendibility; accordingly, we can conduct extensible analysis of compound elements to obtain multiple approaches to solve contradictory problems. Please refer to reference [6], or you may infer by yourself according to the extensible analysis of a basic-element.

2.5.3 Transformation of Compound Elements

Suppose Z_0 is a compound element composed of matter-element, affair-element and relation-element. Conduct certain transformations T of Z_0 to change it to another compound element Z or several compound elements Z_1, Z_2… Z_n, we call transformation T the transformation of compound element Z_0, referred to as transformation of compound element for short.

The transformation of matter-element in compound element complies with the transformation rule of matter-element; the transformation of affair-element in compound element complies with the transformation rule of affair-element, while the transformation of the relation-element in compound element complies with the transformation rule of the relation-element, which is not introduced herein in detail.

2.6 Extension Set

2.6.1 Concept of Extension Set

Extension set theory is one of the theoretical pillars for Extenics. Extension set is another concept of set developed on the basis of classical set and fuzzy set. Set is a mathematical method to describe the recognition and classification of objective things by human brains. Objective things are complicated and ever-moving and changing. Therefore, identification and classification of objective things by the thinking of the human brain are not in one mode only, but in many forms, and the set theory that describes this kind of recognition and classification is accordingly not unique, but diversified. Classical set describes a definite concept of things, using two numbers of 0 and 1 to represent the object belonging to or not belonging to the set; fuzzy set describes fuzziness of things, using the number in [0, 1] to describe the degree of how the thing owns certain property, while extension set describes the variability of things, using the number in $(-\infty, +\infty)$ to describe the degree of how the thing owns certain property, and using an extensible field to describe the reciprocal transformation between the "positive" and "negative" of things.

For example, certain kind of work pieces processed by certain enterprises can be divided into nonconforming products and conforming products by the division method of a classical set. But actually, among the nonconforming products, if the method of "reprocessing" is adopted, the work pieces with dimensions more than standard are "reworks", while the remaining products are scraps; if the method of "electroplating" is adopted, the work pieces with dimensions less than standard are "reworks", while the remaining products are scraps. It can be seen that "reworks" are a kind of special nonconforming product depending on transformation.

This type of problem cannot be described by classical set or fuzzy set, while extension set is a concept developed exactly in the background of these practical problems. It can describe not only the reciprocal transformation between the positive and negative of things, but also the degree of how the thing owns a property, i.e. describing the process of both qualitative and quantitative changes of things. The proposal of extension set provides a theoretical basis for quantification, formalization and logicalization of the process of solving contradictory problems, and new mathematical tool for solving contradictory problems.

1. Definition of Extension Set

Definition 2.23 Suppose U is universe of discourse, u is any one element in U, k is a mapping of U to the real field I, $T=(T_U, T_k, T_u)$ is given transformation, we call

$$\tilde{E}(T)=\{(u,y,y')\mid u\in U,\quad y=k(u)\in I;\ T_u u\in T_U U,\ y'=T_k k(T_u u)\in I\}$$

an extension set on the universe of discourse U, $y=k(u)$ the dependent function of $\tilde{E}(T)$, and $y'=T_k k(T_u u)$ the extension function of $\tilde{E}(T)$, wherein, T_U, T_k *and* T_u are transformations of respective universe of discourse U, dependent function k and element u.

if $T\neq e$, we call

$$\underset{\bullet}{E}_+(T)=\{(u,y,y')\mid u\in U,\ y=k(u)\leqslant 0;\ T_u u\in T_U U,\ y'=T_k k(T_u u)>0\}$$

positive extensible field (or positive qualitative change field)of $\tilde{E}(T)$; we call

$$\underset{\bullet}{E}_-(T)=\{(u,y,y')\mid u\in U,\ y=k(u)\geqslant 0;\ T_u u\in T_U U,\ y'=T_k k(T_u u)<0\}$$

negative extensible field (or negative qualitative change field)of $\tilde{E}$ (T); we call

$$E_+(T)=\{\ (u,y,y')\mid u\in U,\ y=k(u)>0;\ T_u u\in T_U U,\ y'=T_k k(T_u u)>0\}$$

positive stable field (or positive quantitative change field)of $\tilde{E}$ (T); we call

$$E_-(T)=\{\ (u,y,y')\mid u\in U,\ y=k(u)<0;\ T_u u\in T_U U,\ y'=T_k k(T_u u)<0\}$$

negative stable field (or negative quantitative change field)of $\tilde{E}$ (T); we call

$$E_0(T)=\{\ (u,y,y')\mid u\in U,\ T_u u\in T_U U,\ y'=T_k k(T_u u)=0\}$$

extension boundary of $\tilde{E}$ (T).

The above definition may be in four special cases as follows:

(1) When $T_U=e$, $T_k=e$, $T_u=e$, i.e. no transformation is implemented, $\tilde{E}(T)=\tilde{E}=\{\ (u,y)\mid u\in U,\ y=k(u)\in I\ \}$, we call

$$E_+=\{\ (u,y)\mid u\in U,\ y=k(u)>0\ \}$$

positive field of $\tilde{E}$; we call

$$E_-=\{\ (u,y)\mid u\in U,\ y=k(u)<0\ \}$$

negative field of $\tilde{E}$; we call

$$E_0=\{\ (u,y)\mid u\in U,\ y=k(u)=0\ \}$$

zero boundary of $\tilde{E}$.

(2) When $T_U=e$, $T_k=e$, $T_U U=U$, $T_k\,k=k$, i.e. transformation T_u is implemented to element u only,

$$\tilde{E}(T)=\tilde{E}(T_u)=\{\ (u,y,y')\mid u\in U,\ y=k(u)\in I;\ T_u u\in U,\ y'=k(T_u\,u)\in I\ \}$$

This extension set is the extension set of transformation about element u.

(3) When $T_U=e$, $T_u=e$, $T_U U=U$, $T_u u=u$, i.e. transformation T_k is implemented to dependent criterion k only,

$$\tilde{E}(T)=\tilde{E}(T_k)=\{\ (u,y,y')\mid u\in U,\ y=k(u)\in I,\ y'=T_k\,k(u)\in I\ \}$$

This extension set the extension set of transformation about dependent function $k(u)$.

(4) When $T_U U\text{-}U\neq\Phi$, i.e. transformation T_U is implemented on universe of discourse U, the dependent criterion k also changes with it, denoted by T_k, and it's specified that when $u\in T_U U-U,\ k(u)<0$,

$$T_k\,k(u)=k'(u)=\begin{cases} k(u)\,, & u\in U\cap T_U U \\ k_1(u), & u\in T_U U-U \end{cases}$$

$$\tilde{E}(T)=\tilde{E}(T_U)=\{\ (u,y,y')\mid u\in U,\ y=k(u)\in I;\ u\in T_U U,\ y'=k'(u)\in I\ \}$$

This extension set is the extension set of transformation about universe of discourse U.

In particular, when $T_u=e$, $T_k=e$ and $T_U U\subset U$, $T_k\,k=k$, $T_u\,u=u$, $y'=k(u)=y$,

$$\tilde{E}\,(T)=\tilde{E}\,(T_U)=\{\,(u,y)\mid u\in T_U U,\ y=k(u)\in I\,\}$$

It can be seen from the above definition that extension set describes the reciprocal transformation between the "positive" and "negative" of things, and it can be used to describe the process of both quantitative change (stable field) and qualitative change (extensible field). Zero boundary and extension boundary are the boundaries of quantitative change, beyond which, things will undergo qualitative change.

As to the above extension set, when $T=e$, universe of discourse U can be divided into three parts:

$$V_+=\{\,u\mid u\in U,\quad k(u)<0\,\},$$

$$V_-=\{\,u\mid u\in U,\quad k(u)>0\,\},$$

$$V_0=\{\,u\mid u\in U,\quad k(u)=0\,\},$$

which are respectively referred to as the positive field, negative field and zero boundary of universe of discourse U, as shown in Figure 2.1:

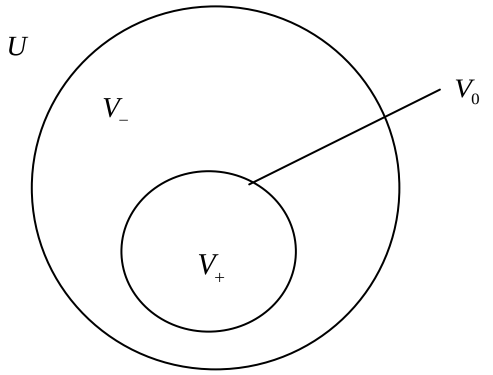


Figure 2.1 Division of Universe of Discourse When *T=e*

When $T\neq e$, taking $T_U=e$, $T_k=e$, $T_u\neq e$ as examples, universe of discourse U can be divided into five parts, corresponding to the four fields and extension boundary of $\tilde{E}\,(T)$, which are respectively denoted as

$$\dot{V}_+(T)=\{\,u\mid u\in U,\ y=k(u)\leqslant 0\ ;\ T_u u\in U,\ y'=k(T_u u)>0\}$$

is referred to as positive extensible field of universe of discourse U about transformation T_u;

$$\dot{V}_-(T)=\{\,u\mid u\in U,\ y=k(u)\geqslant 0\ ;\ T_u u\in U,\ y'=k(T_u u)<0\}$$

is referred to as negative extensible field of universe of discourse U about transformation T_u;

$$V_+(T)=\{\,u\mid u\in U,\ y=k(u)>0;\ T_u u\in U,\ y'=k(T_u u)>0\}$$

is referred to as positive stable field of universe of discourse U about transformation T_u;

$$V_-(T)=\{\,u\mid u\in U,\ y=k(u)<0\ ;\ T_u u\in U,\ y'=k(T_u u)<0\}$$

is referred to as negative stable field of universe of discourse U about transformation T_u;

$$V_0(T)=\{\,u\mid u\in U,\ T_u u\in U,\ y'=k(T_u u)=0\}$$

is referred to as extension boundary of universe of discourse U about transformation T_u, as shown in Figure 2.2:

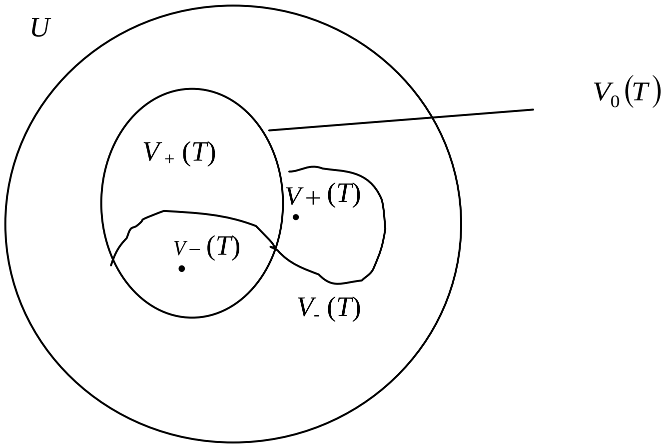


Figure 2.2 Division of Universe of Discourse by Extension Set about Elements Transformation

The above concept of extension set can be used as a theoretical basis and a quantification tool for transforming contradictory problems. For easy understanding and application, familiarized interpretation of extension set is given as follows.

2. Familiarized Interpretation of Extension Set

Meaning of every field in extension set is given in the case of recruitment of employees by a company as follows.

Suppose universe of discourse U is the candidates as a whole at recruitment by a certain company, $u \in U$ is any one candidate, $y=k(u)$ indicates the degree how deep candidate u meets recruitment requirements, then the extension set of universe of discourse U is

$$\tilde{E}(T) = \{(u, y, y') | u \in U, y = k(u) \in I;\ \ T_u u \in T_U U,\ \ y' = T_k k(T_u u) \in I\}$$

wherein T=(T_U, T_k, T_u) is certain transformation implemented, I is field of real number.

(1) When transformation T is not implemented, the positive field of $\tilde{E}$ is

$$E_+ = \{\ (u, y)\ |\ u \in U, y = k(u) > 0\}$$

which indicates all candidates who meet recruitment requirements as a whole. While the negative field of $\tilde{E}$ is

$$E_- = \{\ (u, y)\ |\ u \in U, y = k(u) < 0\}$$

which indicates all candidates who do not meet recruitment requirements as a whole. It's zero boundary

$$E_0 = \{\ (u, y)\ |\ u \in U, y = k(u) = 0\}$$

which indicates all candidates who do and do not meet recruitment requirements as a whole, such as the candidate who has passed certain certificate examination but the certificate has not been issued.

(2) Suppose certain requirements for computer operating levels are given in the recruitment requirement. Universe of discourse and dependent criterion are the same, transformation T_u is intensive training on computer operation of one week for candidates, and some candidates improved their computer operation level after the training, then the positive extensible field.

$$\underset{\bullet}{E}_+(T_u)=\{(u,y,y') \mid u\in U, y=k(u)\le 0; T_u u\in U, y'=k(T_u u)>0\}$$

indicates the candidates as a whole who have been nonconforming but become conforming after intensive training. Because these persons are changed to the employed, they may make the original conforming candidates who have lower computer operating levels than them to be eliminated because of the limited number of recruitment posts, the negative extensible field

$$\underset{\bullet}{E}_-(T_u)=\{(u,y,y') \mid u\in U, y=k(u)\ge 0; T_u u\in U, y'=k(T_u u)<0\}$$

indicates the candidates as a whole who were originally conforming but were eliminated later.

Positive stable field

$$E_+(T_u)=\{(u,y,y') \mid u\in U, y=k(u)>0; T_u u\in U, y'=k(T_u u)>0\}$$

indicates the candidates as a whole who were originally conforming and are still conforming after transformation T_u.

Negative stable field

$$E_-(T_u)=\{(u,y,y') \mid u\in U, y=k(u)<0; T_u u\in U, y'=k(T_u u)<0\}$$

indicates the candidates as a whole who were originally nonconforming and are still nonconforming after transformation T_u.

(3) If the universe of discourse and the persons in universe of discourse are the same, transformation T_k is about dependent criterion k, then the extension set is

$$\tilde{E}(T_k)=\{(u,y,y') \mid u\in U, y=k(u)\in I; y'=T_k k(u)\in I\}$$

Suppose T_k is the change of certain recruitment conditions, such as a lowering of requirements for education, and reinforcing the requirement for language, then the positive extensible field $\underset{\bullet}{E}_+(T_k)$ indicates the candidates as a whole who were originally nonconforming and become conforming after transformation of recruitment conditions, the negative extensible field $\underset{\bullet}{E}_-(T_k)$ indicates the candidates as a whole who were originally conforming and became nonconforming after transformation of recruitment conditions, the positive stable field $E_+(T_k)$ indicates the candidates as a whole who were originally conforming and are still conforming after the transformation, and the negative stable field $E_-(T_k)$ indicates the candidates as a whole who were nonconforming and are still nonconforming after the transformation.

(4) If transformation T_U is about the universe of discourse U, then the extension set is

$$\tilde{E}(T_U)=\left\{\ (u,y,y')\ \middle|\ u\in U,\ y=k(u)\in I; u\in T_U U,\ y'=k'(u)\in I\ \right\}$$

wherein

$$k'(u)=\begin{cases} k(u), & u\in U\cap T_U U \\ k_1(u), & u\in T_U U-U \end{cases}$$

i.e. when the candidates are within the intersection of the new universe of discourse $T_U U$ and the original universe of discourse, the recruitment conditions are the same; when the candidates are out of the original universe of discourse U, the recruitment conditions should be changed, of course, the recruitment conditions now may be the same to or may be different from the original ones, i.e. $k_1(u)$ may be equal to $k(u)$, or may not be equal to $k(u)$.

Suppose T_U is the expansion of the recruitment region, with other recruitment conditions as the same, for example, the original recruitment region was Beijing, i.e. universe of discourse U={all population at appropriate age in Beijing region}, and now is expanded to the whole country, i.e. $T_U U$={all population at appropriate age nationwide}, then the positive extensible field $\underset{\bullet}{E}_{+}(T_U)$indicates the candidates as a whole who are not in Beijing City and become conforming after transformation, and the negative extensible field $\underset{\bullet}{E}_{-}(T_U)$ indicates all applications as a whole who were conforming candidates in Beijing City and become nonconforming because of adding the population from outside the city, the positive stable field $E_{+}(T_U)$ indicates all candidates as a whole who were conforming and are still conforming after the transformation, and the negative field $E_{-}(T_U)$ indicates all candidates as a whole who were nonconforming and are still nonconforming after the transformation.

Thus it can be seen that extension set can express the transformation of things by quantification, and it can be utilized for the changeable classification of things.

In summary, the core concept of extension set is an extensible field that can be divided into a positive extensible field and a negative extensible field. A positive extensible field indicates partial elements of the non-field of classical set or outside the universe of discourse, and they do not have certain property, but can be transformed to have the property because of extension transformation (including transformation of the element itself, transformation of dependent criterion, and transformation of the universe of discourse). It's obvious that different transformations have different extensible fields. The element in extensible field undergoes qualitative change through transformation. The proposal of the extensible field provides a theoretical basis for the transformation of contradictory problems to non-contradictory problems. It's particularly specified:

$$y'=T_k k(T_u u)=k(u,T)$$

(i) when

$$k(u)k(u,T)<0$$

We call T qualitative transformation.

(ii) when

$$k(u)k(u,T)>0$$

We call T quantitative transformation.

(iii) when

$$k(u) < k(u,T)$$

We call T efficiency increasing transformation.

(iv) when

$$k(u) > k(u,T)$$

We call T efficiency decreasing transformation.

Opposite to the extensible field, a stable field indicates the element without qualitative change of its property under certain transformations. Changes of things within stable fields belong to the range of quantitative change.

As mentioned above, extension set has two borders: zero boundary and the boundary of universe of discourse. Transformation of the universe of discourse is reflected by the change of its boundary, transformation of dependent criterion which is reflected by the change of the zero boundary – the border between positive field and negative field, change of element is the change of its position, familiarly speaking, extension transformation can be reflected by the transformations of two borders and elements.

2.6.2 Basic-Element Extension Set

Basic-element extension set is the combined part of basic-element theory and extension set theory. In a basic-element extension set, the element in the universe of discourse may be matter-element, affair-element or relation-element. Basic-element has an internal structure, and the transformation of three key elements of basic-element may change its position in extension set, so basic-element extension set is allowed to become the quantification tool to describe the variability of things.

The concept of the extension set of basic-elements with single evaluated characteristics is first introduced as follows.

1. Concept of Extension Set of Basic-Elements with Single Evaluated Characteristics

Definition 2.24 (extension set of basic-elements with single evaluated characteristics) given set of basic-elements (1-dimentional or multi-dimensional basic-elements)

$$S=\{B\}=\{B \mid B=(O, C, V), O\in U, C\in \mathcal{L}(C), V\in V(C)\}$$

Suppose that c_0 is the evaluated characteristic of B, measure value $c_0(B)=x$, value domain $V(c_0)$, positive field X_0, $X_0 \subset V(c_0)$, real number field $\boldsymbol{I}$, we establish dependent function $k(x)$. As to the given transformation $T=(T_S, T_k, T_B)$, with universe of discourse S, we make dependent function $K(B)=k(x)$, and call

$$\tilde{E}(B)(T)=\{ (B, Y, Y') \mid B\in S, Y=K(B)=k(x)\in \boldsymbol{I}; T_B B\in T_S S,$$

$$Y' = T_K K(T_B B)= T_k k(x')\in \boldsymbol{I}, x' = c_0(T_B B)\}$$

one basic-element extension set on S.

Similar to the definition of extension set 2.23, when $T=e$, basic-element extension set $\tilde{E}(B)(T)=\tilde{E}(B)$, it divides basic-element universe of discourse S into the positive field, the negative field and zero boundary, i.e.

$$E_+(B)=\{B \mid B \in S,\ Y=K(B)>0\}$$

is positive field of S;

$$E_-(B)=\{B \mid B \in S,\ Y=K(B)<0\}$$

is negative field of S;

$$E_0(B)=\{B \mid B \in S,\ Y=K(B)=0\}$$

is zero boundary of S about basic-element extension set $\tilde{E}(B)$.

$$\underset{\bullet}{E}_+(B)(T)=\{(B,Y,Y') \mid B \in S, Y=K(B) \le 0; \\ T_B B \in T_S S, Y'=T_K K(T_B B)>0\}$$

$$\underset{\bullet}{E}_-(B)(T)=\{(B,Y,Y') \mid B \in S, Y=K(B) \ge 0; \\ T_B B \in T_S S, Y'=T_K K(T_B B)<0\}$$

are called respectively positive extensible field and negative extensible field of $\tilde{E}(B)(T)$;

$$E_+(B)(T)=\{(B,Y,Y') \mid B \in S,\quad Y=K(B)>0; T_B B \in T_S S,\ Y'=T_K K(T_B B)>0\}$$

$$E_-(B)(T)=\{(B,Y,Y') \mid B \in S,\quad Y=K(B)<0; T_B B \in T_S S,\ Y'=T_K K(T_B B)<0\}$$

are called respectively positive stable field and negative stable field of $\tilde{E}(B)(T)$;

$$E_0(B)(T)=\{(B,Y,Y') \mid B \in S,\ T_B B \in T_S S, Y'=T_K K(T_B B)=0\}$$

is called extension boundary of $\tilde{E}(B)(T)$.

Accordingly, the basic-element extension set about basic-element transformation can divide the basic-element universe of discourse S into a positive extensible field, negative extensible field, positive stable field, negative stable field and an extension boundary.

In particular, when B is one-dimensional matter-element and $c_0 = c$, i.e. $B=(O, c_0, v)$, $k(x) = k(v)$. If $T=e$, $\tilde{E}(B)$ is the matter-element extension set defined in reference [2].

Similar to general extension set, basic-element extension set is capable of quantitative expression of basic-element transformation, and can be used for changeable classification of basic-elements.

2. Concept of Extension Set of Basic-Elements with Multiple Evaluated Characteristics

The above definition of basic-element extension set is pertinent to single evaluated characteristics. When a certain problem requires evaluating the element (basic-element) in the universe of discourse by multiple evaluation characteristics, extension set of basic-elements with multiple evaluated characteristics should be established, which is the theoretical basis for comprehensive evaluation of multiple characteristics and solving incompatible problems with multiple characteristics.

Definition 2.25 As to the set of basic-elements $S=\{B\}$, suppose $c_0=(c_{01}, c_{02}, \ldots, c_{0m})$ is m evaluated characteristics of B, measure value of B about c_0 is

$$c_0(B)=(c_{01}(B), c_{02}(B), \ldots, c_{0m}(B)) \stackrel{\Delta}{=} (x_1, x_2, \ldots, x_m)$$

$V(c_{0i})$ is value domain of x_i, X_{0i} is positive field, $X_{0i} \subset V(c_{0i})$, the established dependent function is $k_i(x_i)$, $i=1, 2, \ldots, m$, denote

$$k(c_0(B))=(k_1(c_{01}(B)), k_2(c_{02}(B)), \ldots, k_m(c_{0m}(B))) =(k_1(x_1), k_2(x_2), \ldots, k_m(x_m))$$

as evaluation vector of B. If the weight coefficient of evaluated characteristics in a certain problem is $\alpha_1, \alpha_2, \cdots, \alpha_m$, and $\sum_{i=1}^{m} \alpha_i = 1$ is met,

$$K(B) = \sum_{i=1}^{m} \alpha_i k_i(c_{0i}(B)) = \sum_{i=1}^{m} \alpha_i k_i(x_i)$$

is called comprehensive dependent degree of B about c_0,

$$\tilde{E}(B)(T) = \{(B,Y,Y') \mid B \in S,\ Y = K(B) \in I; T_B B \in T_S S, Y' = T_K K(T_B B) \in I\}$$

is called extension set of basic-elements with multiple evaluated characteristics on S.

As to comprehensive dependent degree, there are the following special cases:

(1) If a certain problem requires that the basic-element be considered meeting requirements only when each evaluated characteristic meets requirements, the definition of comprehensive dependent degree is

$$K(B) = \bigwedge_{i=1}^{m} k_i(c_{0i}(B)) = \bigwedge_{i=1}^{m} k_i(x_i)$$

wherein $\bigwedge_{i=1}^{m}$ indicates taking the minimum one from m values.

(2) If a certain problem requires that the basic-element be considered meeting the requirement when at least one evaluated characteristic meets the requirement, the comprehensive dependent degree is

$$K(B) = \bigvee_{i=1}^{m} k_i(c_{0i}(B)) = \bigvee_{i=1}^{m} k_i(x_i)$$

wherein $\bigvee_{i=1}^{m}$ indicates taking the maximum one from m values.

(3) If the measure value domain about a certain characteristic c_{0i_0} is designated as a condition that must be met, first to use this characteristic to sift all basic-elements, and then to use other evaluated characteristics to establish the function of comprehensive dependent degree for the basic-elements that meet the condition.

In the extension set of basic-elements with multiple evaluated characteristics, as to each basic-element B_i in universe of discourse S, if $K(B_i)>0$, it's considered the basic-element B_i meets the requirement; if $K(B_i)<0$, it's considered the basic-element B_i does not meet the requirement; if $K(B_i)=0$, conduct specific analysis on the specific problem, because zero boundary element is a condition to be met in some practical problems, but is not in other practical problems.

If there is basic-element, meeting

$$K(B_0)=\max_{1\le i\le n}\{K(B_i),B_i\in S\}$$

it indicates the highest comprehensive dependent degree of B_0, i.e. maximum superiority (the degree of meeting comprehensive requirement), which can be used as a quantification basis for solving contradictory problems.

The formalized definitions of an extension market and an extension resource introduced in 5.4 of chapter 5 in this book are applications of basic-element extension sets.

2.7 Dependent Function

In classical mathematics, whether the element in the universe of discourse with a certain property is described by a characteristic function, by 0 and 1 that describe yes and no.

In fuzzy mathematics, the degree to which the element in the universe of discourse has certain property is expressed by the membership function, by a value from [0, 1].

While in extension mathematics, the degree to which the element in the universe of discourse has certain property is scored by dependent functions. The established basic formula of dependent functions of extension sets in real fields can quantitatively and objectively express the degree to which the element has certain property and the process of its quantitative and qualitative changes.

2.7.1 Concept of Distance (in Extenics) – Difference from and Association with Distance (in Classical Mathematics)

1. Definition of distance in classical mathematics

The distance between point x and point y on a real number axis is: $\rho(x,y)=|x-y|$

The distance between point x on a real number axis and finite interval X=<a,b>①:

$$d(x,X)=\begin{cases}0, & x\in X\\ \inf\limits_{y\in X}\rho(x,y), & x\notin X\end{cases}$$

It's specified by the basic concept of "distance" that "the distance between any point in interval and the interval is zero". Therefore, it materially specifies the qualitative description that "all are the same in the class", and cannot express the "quantitative change" and "qualitative change" of things.

Note ①: the expression method of interval <a,b> in this book is slightly different from that in classical mathematics, which can indicate an open interval, a closed interval, or a half-open and half-closed interval.

2. Definition of distance in Extenics

The distance in Extenics called extension distance**.** In order to describe the difference of things in a class, before establishing dependent function, the extension distance between point x and interval X=<a,b> is specified [2]:

Definition 2.26 Suppose x is any point in real axis, and X =<a,b> is any interval in real field, we call

$$\rho(x,X)=\left|x-\frac{a+b}{2}\right|-\frac{b-a}{2} \qquad (1)$$

the extension distance between point x and interval X , where <a,b> can be an open interval, a closed interval, or a half-open and a half-closed interval.

As to any point x_0 on real axis, we have:

$$\rho(x_0,X)=\left|x_0-\frac{a+b}{2}\right|-\frac{b-a}{2}=\begin{cases}a-x_0, & x_0\le\frac{a+b}{2}\\ x_0-b, & x_0\ge\frac{a+b}{2}\end{cases}$$

Nature 2.1 Given interval *X*=<*a*, *b*>, then

a) Point $x\in X$, and $x\neq a, b$, necessary and sufficient condition is $\rho(x,X)$<0

b) Point $x\notin X$, and $x\neq a, b$, necessary and sufficient condition is $\rho(x,X)$>0

c) Point $x=a$ or $x=b$' necessary and sufficient condition is $\rho(x,X)$=0

Nature 2.2 If X_1, X_2 are two intervals on a real axis, $X_2\supset X_1$, without a common endpoint, then for any *x*, there is

$$\rho(x,X_2)<\rho(x,X_1)$$

3. Association between extension distance ρ (*x*, X) and distance *d* (*x*, X) in classical mathematics

The association between point-interval extension distance $\rho(x, X)$ and point-interval distance $d(x, X)$ in classical mathematics is:

① when $x\notin X$ or $x=a, b$, $\rho(x, X)=d(x, X)\geq 0$;

② when $x\in X$ and $x\neq a, b$, $\rho(x, X)<0$, $d(x, X)=0$.

The introduced concept of extension distance can precisely score the locational relation between a point and an interval in quantitative form. When the point is in the interval, it's considered by classical mathematics that the distance between any point and the interval is 0; while in extension set, the difference of locations of the point in the interval can be described according to different values of distance, by using the concept of extension distance. The description of locational relation between a point and an interval by the concept of extension distance allows the development from "all are the same in the class" to a quantitative description of different degrees in the class.

[Example 2. 11] Given interval *X*=<3, 5>, to obtain ρ (2, X), ρ (5, X), ρ (7, X)

$$\rho(2,X)=\left|2-\frac{3+5}{2}\right|-\frac{1}{2}(5-3)$$

$$\rho(5,X)=\left|5-\frac{3+5}{2}\right|-\frac{1}{2}(5-3)=0;$$

$$\rho(4,X)=\left|4-\frac{3+5}{2}\right|-\frac{1}{2}(5-3)=-1.$$

2.7.2 Definition of Place Value

In practical problems, we should not only consider the locational relation between a point and an interval, but also frequently consider the locational relation between intervals and between one point and two intervals.

For example, there is an ideal range of the requirement for an electric current by normal operation of a motor, i.e. the commonly referred rated current <20A, 50A>. In practical problems, there is another acceptable range of current quantity, such as <15A, 53A>, and the motor is truly incapable of operation or burned only out of this range. A nest of intervals is formed by these two intervals, and the relation between a point and these two intervals is described by place value.

The concept of place value is as follows.

Definition 2.27 Suppose $X_0 =< a_0, b_0 >$, $X =< a, b >$, and $X_0 \subset X$, then it's specified the place value of point x about the nest of interval composed of intervals X_0 and X is

$$D(x, X_0, X) = \rho(x, X) - \rho(x, X_0) \qquad (2)$$

$D(x, X_0, X)$ describes the locational relation between point x and the nest of intervals composed of X_0 and X.

According to the definition of extension distance and place value, we obviously have: when X_0 and X have no common endpoints, we have $D(x, X_0, X)<0$; when X_0 and X have common endpoints, we have $D(x, X_0, X) \le 0$.

[Example 2.12] Given X_0=<3, 5>, X=<1, 9>, to obtain $D(2, X_0, X)$, $D(4, X_0, X)$, $D(6, X_0, X)$, and $D(10, X_0, X)$.

Solution: according to formula (2), we obtain:

$$
\begin{aligned}
D(2,X_0,X) &= \rho(2,X)-\rho(2,X_0)\\
&= \left|2-\frac{1+9}{2}\right|-\frac{1}{2}(9-1)-\left|2-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 3-4-2+1=-2
\end{aligned}
$$

$$
\begin{aligned}
D(4,X_0,X) &= \rho(4,X)-\rho(4,X_0)\\
&= \left|4-\frac{1+9}{2}\right|-\frac{1}{2}(9-1)-\left|4-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 1-4-0+1=-2
\end{aligned}
$$

$$
\begin{aligned}
D(6,X_0,X) &= \rho(6,X)-\rho(6,X_0)\\
&= \left|6-\frac{1+9}{2}\right|-\frac{1}{2}(9-1)-\left|6-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 1-4-2+1=-4
\end{aligned}
$$

$$
\begin{aligned}
D(10,X_0,X) &= \rho(10,X)-\rho(10,X_0)\\
&= \left|10-\frac{1+9}{2}\right|-\frac{1}{2}(9-1)-\left|10-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 5-4-6+1=-4
\end{aligned}
$$

[Example 2.13] Given X_0=<3, 5>, X=<3, 9>, to obtain $D(2,X_0,X)$, $D(6,X_0,X)$, and $D(10,X_0,X)$.

Solution: according to formula (2):

$$
\begin{aligned}
D(2,X_0,X) &= \rho(2,X)-\rho(2,X_0)\\
&= \left|2-\frac{3+9}{2}\right|-\frac{1}{2}(9-3)-\left|2-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 4-3-2+1=0
\end{aligned}
$$

$$
\begin{aligned}
D(6,X_0,X) &= \rho(6,X)-\rho(6,X_0)\\
&= \left|6-\frac{3+9}{2}\right|-\frac{1}{2}(9-3)-\left|6-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 0-3-2+1=-4
\end{aligned}
$$

$$
\begin{aligned}
D(10,X_0,X) &= \rho(10,X)-\rho(10,X_0)\\
&= \left|10-\frac{3+9}{2}\right|-\frac{1}{2}(9-3)-\left|10-\frac{3+5}{2}\right|+\frac{1}{2}(5-3)\\
&= 4-3-6+1=-4
\end{aligned}
$$

2.7.3 Construction of Elementary Dependent Function of Optimal Point at Interval Midpoint

As mentioned above, the requirement for some indexes by many practical problems has two intervals: measure-conforming (or ideal) interval and acceptable (or qualitative change's) interval. For example, load requirements by mechanical operation; control range of dose in medicine; Confucius's "doctrine of mean" – too much is as bad as too little. In order to describe these practical problems by formula, the basic formula for elementary dependent function of the optimal point at interval midpoint was established respectively in the references [2] and [11], and later various formulae to construct dependent functions have been successively established in many papers and treatises. This book sorts out theses formulae, proposes several basic formulae, and explicitly defines several basic concepts. Any inconsistency with the previous treatise of the author should be subject to this book.

2.7.3.1 Several Basic Concepts

In our real life, the qualifying degree of the measure of an object in universe of discourse U about certain characteristic usually has a desirable interval $X_0=<a_0, b_0>$ and an acceptable interval $X=<a, b>$, and it's obvious that $X\supset X_0$. For example, when buying a piece of clothing, there is a desirable price interval in one's mind <200 yuan, 250 yuan >, and an acceptable price interval <200 yuan, 280 yuan>. During product inspection, the work piece conforming diameter is <5cm, 5.1cm>, as a desirable interval, but during measurement by vernier calipers, a deviation of ±0.01cm is allowable, in other words, <4.99cm, 5.11cm> is an acceptable interval.

When no transformation is implemented, the measure of the object about certain characteristic is within the acceptable interval $<a, b>$, which indicates the object has certain property, with degree expressed by a real number between $(0,+\infty)$, and these objects constitute the "positive field" in the static extension set introduced in section 2.6; Contrarily, when the measure of object about certain characteristic is out of the acceptable interval $<a, b>$, it's indicated that the object does not have certain property, with degree expressed by a real number between $(-\infty,0)$, and these objects constitute the "negative field" in the static extension set introduced in section 2.6; when the measure value of object about certain characteristic is a or b, the corresponding object is critical object with corresponding dependent function value of zero, and the whole constitute the "zero boundary" in the static extension set introduced in section 2.6.

Here we call the desirable interval $X_0=<a_0, b_0>$ standard positive field, and interval $X_+=<a, a_0>\cup<b_0, b>$ transition positive field.

Similar to a positive field, a negative field also has a transition negative field and a standard negative field. For example, the motor in a hydropower station frequently operates under the level of dead water, and fails only when the water level drops under a certain threshold. In other words, there is a transitional process for when an object changes from its critical state to losing certain property.

Suppose a real number field is $\Re$, denote transition negative field by $X_-=<c, a>\cup<b, d>$, let $\hat{X}=X\cup X_-=<c, d>$, the interval of measures in negative field is $\overline{X}=\Re-X$, and the interval of measures in standard negative field is $\overline{X}_0=\Re-\hat{X}$. Thus, the Universe of discourse U can be classified into

$$\text{Universe of discourse } U\begin{cases}\text{Positive field}\begin{cases}\text{Standard positive field}\\ \text{Transition positive field}\end{cases}\\ \text{Criticality}\\ \text{Negative field}\begin{cases}\text{Standard negative field}\\ \text{Transition negative field}\end{cases}\end{cases}$$

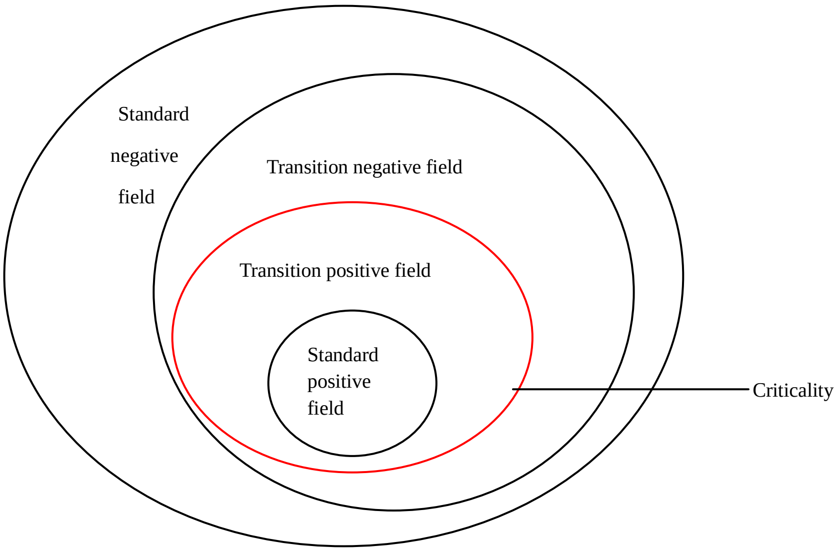


Figure 5 Classification of Universe of Discourse *U*

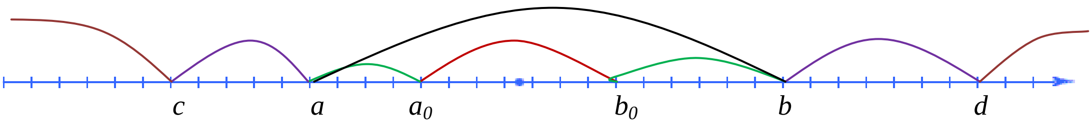


Figure 6 Relations among Intervals $<a_0, b_0>$, $<a, b>$and $<c, d>$

The selected nest of intervals is different according to different requirements by practical problems, so the constitution method of dependent function of the optimal point at interval midpoint is also different.

2.7.3.2 Constitution Method of Elementary Dependent function

1. Suppose $x \in X$, i.e. point *x* belongs to positive field, now the constitution of dependent function can be in two cases:

(1) In the case that positive field and standard positive field have no common endpoint

If the selected nest of intervals is constituted by positive field *X* and standard positive field X_0, i.e. $X_0=<a_0,b_0>$, $X=<a, b>$, $X \supset X_0$, and *X* and X_0 have no common endpoint, then, the form of elementary dependent function is

$$k(x) = \frac{\rho(x, X)}{D(x, X_0, X)} \tag{3}$$

This dependent function meets the following conditions:

1) When $x \in X_0$, $k(x) \geq 1$;

2) When $x \in X - X_0$, $0 < k(x) \leq 1$;

3) When $x = a \vee b$, $k(x) = 0$;

4) When $x = \frac{a_0 + b_0}{2}$, $k(x)$ reaches the maximum value.

In formula (3), $D(x, X_0, X)$ is place value between point *x* and intervals X_0 and X, because *X* and X_0 have no common endpoint, we obviously have $D(x, X_0, X) = \rho(x, X) - \rho(x, X_0) \neq 0$.

(2) In the case that positive field and standard positive field have common endpoint

If $D(x, X_0, X) = \rho(x, X) - \rho(x, X_0) = 0$, it's indicated that standard positive field X_0 and positive field X have common endpoints, now it's specified that

$$k(x) = \begin{cases} -\rho(x, X_0) + 1, & D(x, X_0, X) = 0, x \in X_0 \\ 0, & D(x, X_0, X) = 0, x \notin X_0, x \in X \end{cases}$$

In summary, when $x \in X$, the elementary dependent function is specified as

$$k(x) = \begin{cases} \dfrac{\rho(x, X)}{D(x, X_0, X)}, & D(x, X_0, X) \neq 0, x \in X \\ -\rho(x, X_0)+1, & D(x, X_0, X)=0, x \in X_0 \\ 0, & D(x, X_0, X)=0, x \notin X_0, x \in X \end{cases} \tag{4}$$

Now, the maximum value of *k*(*x*) is reached at the midpoint of interval X_0.

2. Suppose $x \in \Re - X$, i.e. point *x* belongs to the negative field, now the construction of the dependent function can also be in two cases:

(1) As mentioned above, suppose the real number field is $\Re$, the transition negative field is $X_{\_}$ =<*c*, *a*>∪<*b*, *d*>, and let $\hat{X} = X \cup X_{\_}$ =<*c*, *d*>. Next, we discuss the construction of the dependent function when the nest of intervals is constituted by $\hat{X}$ and positive field *X*, i.e. *X*=<*a*, *b*>, $\hat{X}$ =<*c*, *d*>, $\hat{X} \supset X$, and these two intervals have no common endpoint, now place the value $D(x, X, \hat{X}) = \rho(x, \hat{X}) - \rho(x, X) \neq 0$, and the elementary dependent function is specified as

$$k(x) = \frac{\rho(x, X)}{D(x, X, \hat{X})} \tag{5}$$

This dependent function meets the following conditions:

1） When $x \in \hat{X} - X$, $-1 \leq k(x) < 0$;

2） When $x = a \vee b$, $k(x) = 0$;

3） When $x \in \Re - \hat{X}$, $k(x) < -1$.

(2) If $D(x, X, \hat{X}) = \rho(x, \hat{X}) - \rho(x, X) = 0$, it's indicated that $X, \hat{X}$ have common endpoints, now it's specified that

$$k(x) = -\rho(x, \hat{X}) - 1$$

In summary, when $x \in \Re - X$, the elementary dependent function is specified as

$$k(x) = \begin{cases} \dfrac{\rho(x, X)}{D(x, X, \hat{X})}, & D(x, X, \hat{X}) \neq 0, x \in \Re - X \\ -\rho(x, \hat{X}) - 1, & D(x, X, \hat{X}) = 0, x \in \Re - X \end{cases} \tag{6}$$

3. Construction method of an elementary dependent function in a real number field $\Re$

Constitute a nest of three intervals by standard positive field X_0, positive field X and interval $\hat{X}$, i.e. $X_0=<a_0, b_0>$, $X=<a,b>$, $\hat{X}=<c,d>$, $\hat{X} \supset X \supset X_0$, then for any $x \in \Re$, the elementary dependent function $k(x)$ of optimal point at the midpoint of interval X_0 is

$$k(x) = \begin{cases} \dfrac{\rho(x, X)}{D(x, X_0, X)}, & D(x, X_0, X) \neq 0, x \in X \\ -\rho(x, X_0) + 1, & D(x, X_0, X) = 0, x \in X_0 \\ 0, & D(x, X_0, X) = 0, x \notin X_0, x \in X \\ \dfrac{\rho(x, X)}{D(x, X, \hat{X})}, & D(x, X, \hat{X}) \neq 0, x \in \Re - X \\ -\rho(x, \hat{X}) - 1, & D(x, X, \hat{X}) = 0, x \in \Re - X \end{cases} \tag{7}$$

The values range of the above dependent function is (—∞, +∞), and this formula can be used to calculate the dependent degree between a point and nest of intervals. By expressing the dependent function in extension set using the above formula, the qualitative description that “the object has property *P*” is extended to the quantitative description of “the degree to which it has the property *P*”.

The establishment of the basic formula of elementary dependent function allows the calculation for the dependent degree of the problem to be independent of subjective judgment or statistics, but to be determined by the range (positive field) required by the measure of the object about a certain characteristic. Thus dependent function gets out of the deviation caused by subjective judgment. In operation, when simply three intervals or two of them are determined, dependent function can be established. Therefore, the calculation formula of dependent function extended from this formula plays an important role for different practical problems.

5. Determination method of a_0, b_0, a, b, c, d

To appropriately establish dependent function, a_0, b_0, a, b, c, d must be properly determined first, generally by the following methods: by professional standards and objective laws obtained from experimental record and historical data, or by statistic measures determined by data mining technology. Different dependent functions should be established for different indexes, and the users must make concrete analysis of a concrete problem.

[Example 2.14] The operating current for a motor is X_0=<20A, 50A>, but actually the motor cannot be started under 15A, and is burnt only above 85A, i.e. the acceptable current interval is X=<15A, 85A>. Suppose the operating state is normal at 35A, try to establish the dependent function expressing that the motor's current meets operating conditions.

Solution: this example belongs to the case of dependent function for the nest of intervals composed of a positive field and a standard positive field without common endpoints, and the dependent function can be established according to formula (3).

$$\begin{aligned}\rho(x,X_0) &= \left|x-\frac{20+50}{2}\right|-\frac{1}{2}(50-20)\\ &= |x-35|-15\end{aligned}$$

$$\rho(x,X)=|x-50|-35$$

$$\begin{aligned}D(x,X_0,X) &= \rho(x,X)-\rho(x,X_0)=|x-50|-35-|x-35|+15\\ &= |x-50|-|x-35|-20\end{aligned}$$

$$K(x)=\frac{\rho(x,X)}{D(x,X_0,X)}=\frac{|x-50|-35}{|x-50|-|x-35|-20}$$

When x=12A, $K(12)=\dfrac{38-35}{38-23-20}=-\dfrac{3}{5}$

When x=30A, $K(30)=\dfrac{20-35}{20-5-20}=\dfrac{-15}{-5}=3$

When x=18A, $K(18)=\dfrac{32-35}{32-17-20}=\dfrac{-3}{-5}=\dfrac{3}{5}$

[Example 2.15] Given positive field X=<3, 7>, $\hat{X}$ =<3, 11>, the optimal point is 5, try to establish the dependent function when $x\notin X$, and obtain $K(2), K(8), K(12)$.

Solution: according to formula (6), because

$$\rho(x,X)=\left|x-\frac{3+7}{2}\right|-\frac{1}{2}(7-3)=|x-5|-2$$

$$\rho(x,\hat{X})=\left|x-\frac{3+11}{2}\right|-\frac{1}{2}(11-3)=|x-7|-4$$

$$D(x,X,\hat{X})=\rho(x,\hat{X})-\rho(x,X)$$
$$=|x-7|-|x-5|-2$$

the following dependent function can be established:

$$k(x)=\begin{cases}\dfrac{\rho(x,X)}{D(x,X,\hat{X})}, & D(x,X,\hat{X})\neq 0,\ \ x\in\Re-X\\ -\rho(x,\hat{X})-1, & D(x,X,\hat{X})=0,\ \ x\in\Re-X\end{cases}$$
$$=\begin{cases}\dfrac{|x-5|-2}{|x-7|-|x-5|-2}, & D(x,X,\hat{X})\neq 0,\ \ x\in(-\infty,3>\cup<7,+\infty)\\ -|x-7|+3, & D(x,X,\hat{X})=0,\ \ x\in(-\infty,3>\cup<7,+\infty)\end{cases}$$

thus we have

$$K(2)=-|2-7|+3=-2$$

$$K(8)=\frac{3-2}{1-3-2}=-\frac{1}{4}$$

$$K(12)=\frac{7-2}{5-7-2}=-\frac{5}{4}$$

2.7.4 Side Distance and Corresponding Elementary Dependent Function

Elementary Dependent function When Optimal Point is not at Interval Midpoint

2.7.4.1 Actual Background to Propose Side Distance

When the optimal point of a certain index in a practical problem is met at the midpoint $x=\dfrac{a+b}{2}$ of interval X_0=<*a*,*b*>, i.e. this point most qualifies for certain requirements, we establish formulae (1)-(7) to calculate the degree to which the index qualifies for certain requirements, now the dependent function reaches its maximum value at $x=\dfrac{a+b}{2}$.

But there is not always this case in practical works. For example, error is the less the better; cost is the lower the better, performance price ratio is the higher the better; the cleaning rate of a washing machine is the higher the better. Generally speaking, the optimal point of a certain index (characteristic value) is not necessarily at the interval midpoint. Therefore, different forms of dependent function must be established according to the requirement of the practical problem.

To establish the basic formula of dependent function in this case, we first introduce the concept of side distance [2].

2.7.4.2 Definition of Side Distance

Definition 2.29 (left side distance) Given interval X =<*a*,*b*>, $x_0 \in (a, \frac{a+b}{2}>$,

$$\rho_l(x, x_0, X) = \begin{cases} a-x, & x \le a \\ \frac{b-x_0}{a-x_0}(x-a), & x \in <a, x_0> \\ x-b, & x \ge x_0 \end{cases} \qquad (8)$$

is called left side distance between *x* and interval X about x_0.

In particular, when $x_0=a$, we take

$$\rho_l(x, a, X) = \begin{cases} a-x, & x < a \\ a_z, & x = a \\ x-b, & x > a \end{cases}$$

where,

$$a_z = \rho_l(a, a, X) = \begin{cases} 0, & a \notin X \\ a-b, & a \in X \end{cases}$$

Definition 2.30 (right side distance) Given interval X =<*a*,*b*>, $x_0 \in <\frac{a+b}{2}, b)$,

$$\rho_r(x, x_0, X) = \begin{cases} a-x, & x \le x_0 \\ \frac{a-x_0}{b-x_0}(b-x), & x \in <x_0, b> \\ x-b, & x \ge b \end{cases} \qquad (9)$$

is called right side distance between *x* and interval X about x_0.

In particular, when $x_0=b$, we take

$$\rho_r(x, b, X) = \begin{cases} a-x, & x < b \\ b_z, & x = b \\ x-b, & x > b \end{cases}$$

where,

$$b_z = \rho_r(b, b, X) = \begin{cases} 0, & b \notin X \\ a-b, & b \in X \end{cases}$$

It can be seen that extension distance is a particular case of side distance, i.e. when $x_0 = \frac{a+b}{2}$,

$\rho\ (x, \frac{a+b}{2}, X) = \rho(x, X)$.

Left side distance and right side distance are expressed by $\rho(x, x_0, X)$ in uniform.

2.7.4.3 Elementary Dependent Function When Optimal Point is Reached at x_0

Similar to the situation when the optimal point is at midpoint, the elementary dependent function when the optimal point is reached at x_0 should also be constructed according to the different composition of the nest of intervals:

1. **If** $x \in X$, i.e. **point *x* belongs to positive field, now the composition of dependent function is as follows:**

Suppose the nest of intervals is composed of a standard positive field X_0=<a_0,b_0> and positive field X =<a,b>,

and $x_0 \in X_0$, $X_0 \subset X$,

① X_0 and X have no common endpoint, then we can establish the elementary dependent function when the optimal point is reached at x_0:

$$k(x) = \frac{\rho(x, x_0, X)}{D(x, X_0, X)} \tag{10}$$

② X_0 and X have common endpoints, then we can establish the elementary dependent function when the optimal point is reached at x_0:

$$k(x) = \begin{cases} \dfrac{\rho(x, x_0, X)}{D(x, X_0, X)}, & D(x, X_0, X) \neq 0, x \in X \\ -\rho(x, x_0, X_0)+1, & D(x, X_0, X)=0, x \in X_0 \\ 0, & D(x, X_0, X)=0, x \notin X_0, x \in X \end{cases} \tag{11}$$

2. **If** $x \in \Re - X$, i.e. **point *x* belongs to a negative field, now the composition of dependent function is as follows:**

Suppose the nest of intervals is composed of $\hat{X}$ =<c,d> and the positive field X =<a,b>, and $x_0 \in$<a,b>, $X \subset \hat{X}$,

① X and $\hat{X}$ have no common endpoint, then we can establish elementary dependent function:

$$k(x) = \frac{\rho(x, x_0, X)}{D(x, X, \hat{X})} \tag{12}$$

② X and $\hat{X}$ have common endpoints, then, we can establish elementary dependent function:

$$k(x) = \begin{cases} \dfrac{\rho(x, x_0, X)}{D(x, X, \hat{X})}, & D(x, X, \hat{X}) \neq 0, x \in \Re - X \\ -\rho(x, x_0, \hat{X}) - 1, & D(x, X, \hat{X})=0, x \in \Re - X \end{cases} \tag{13}$$

3. If $x \in \Re$, i.e. point x belongs to real number field, now by combining the two cases above, the dependent function of optimal point reached at x_0 can be constructed as follows:

$$k(x)=\begin{cases}\dfrac{\rho(x,x_0,X)}{D(x,X_0,X)}, & D(x,X_0,X)\neq 0, x\in X\\ -\rho(x,x_0,X_0)+1, & D(x,X_0,X)=0, x\in X_0\\ 0, & D(x,X_0,X)=0, x\notin X_0, x\in X\\ \dfrac{\rho(x,x_0,X)}{D(x,X,\hat{X})}, & D(x,X,\hat{X})\neq 0, x\in \Re - X\\ -\rho(x,x_0,\hat{X})-1, & D(x,X,\hat{X})=0, x\in \Re - X\end{cases} \tag{14}$$

The problem should be noticed when applying elementary dependent function: when applying the formula of dependent function, it must be noticed whether the optimal value x_0 of measure is at the midpoint, or the left side or right side of the midpoint of interval X_0, and the formula must be selected strictly according to the above formulae. Applying the same formula without discriminating the specific case will lead to incorrect conclusions.

2.7.5 Interval Elementary Dependent Function

Elementary Dependent Function Based on Interval Distance and Interval Side Distance

Because of the complexity of the system and the uncertainty of the information, people can hardly obtain the precise measure of objects about some characteristics, and can hardly establish precise dependent function by consequence. Therefore, interval elementary dependent function should be studied. References [12] and [13] proposed the concepts of interval distance, interval side distance and interval place value, etc., discussed relevant natures, respectively constructed the calculation formulae of interval elementary dependent function based on the interval distance and interval side distance, obtained some natures, and better solved the problem of quantification in the case that the measure of the basic-element was imprecisely measured, as the extension of the elementary dependent function introduced above. This method is featured by a simple and concise conclusion and easy operation. The proposal of interval elementary dependent function provides effective tools for extensible analysis and the evaluation of basic-elements in the case of imprecise measurements. Relevant study is continuously proceeding, and the interested reader may wish to r the corresponding reference page.

2.7.6 Simple Dependent Function

1. Positive field is finite interval $X=<a,b>$, and max. value point $M\in(a,b)$

$$k(x)=\begin{cases}\dfrac{x-a}{M-a}, & x\leq M\\ \dfrac{b-x}{b-M}, & x\geq M\end{cases}$$

then $K(x)$ meets the following natures:

① $K(x)$ reaches its maximum value at $x=M$, and $k(M)=1$;

② $x \in X$, and $x \neq a, b \Leftrightarrow k(x) > 0$

③ $x \notin X$, and $x \neq a, b \Leftrightarrow k(x) < 0$

④ $x = a$ or $x = b \Leftrightarrow k(x) = 0$

Particular case: when $M = \dfrac{a+b}{2}$,

$$k(x) = \begin{cases} \dfrac{2(x-a)}{b-a}, & x \leq \dfrac{a+b}{2} \\ \dfrac{2(b-x)}{b-a}, & x \geq \dfrac{a+b}{2}. \end{cases}$$

and $k(x)$ reaches maximum at midpoint $M = \dfrac{a+b}{2}$.

2. Positive field is finite interval $X = \lt a, b \gt$, and max. value is obtained at $M = a$ or b

(1) When $M = a$,

$$k(x) = \begin{cases} \dfrac{x-a}{b-a}, & x < a \\ \dfrac{b-x}{b-a}, & x \geq a \end{cases}$$

(2) When $M = b$,

$$k(x) = \begin{cases} \dfrac{x-a}{b-a}, & x \leq b \\ \dfrac{b-x}{b-a}, & x > b \end{cases}$$

[Example 2.16] Establish the dependent function of the conforming degree of work piece: diameter $\Phi\ \mathbf{30^{+0.01}_{-0.02}}$, X=<29.98, 30.01>, M=30.

Solution: according to the formula for the dependent function with a positive field that is a finite interval, we have

$$k(x) = \begin{cases} \dfrac{x-29.98}{30-29.98}, & x \leq 30 \\ \dfrac{30.01-x}{30.01-30}, & x \geq 30 \end{cases}$$
$$= \begin{cases} 50(x-29.98), & x \leq 30 \\ 100(30.01-x), & x \geq 30 \end{cases}$$

When x=30.1, $k(30.1) = 100(30.01-30.1) = -9$

When x=29.99, $k(29.99) = 50(29.99 - 29.98) = 0.5$

When x=30, $k(30) = 100(30.01 - 30) = 50(30 - 29.98) = 1$

When x=29, $k(29) = 50(29 - 29.98) = -49$

3. Positive field is infinite interval $X =< a, +\infty),$ and max. value point $M \in X$

$$k(x) = \begin{cases} \dfrac{x-a}{M-a}, & x \le M \\ \dfrac{M}{2x-M}, & x \ge M \end{cases}$$

Particular case 1: when $M = a$,

$$k(x) = \begin{cases} x-a, & x < a \\ \dfrac{a}{2x-a}, & x \ge a \end{cases}$$

Particular case 2: if function $k(x)$ has no maximum value at $X =< a, +\infty)$, we take $k(x)=x-a$

3. Positive field is infinite interval $X = (-\infty, b >,$ and max. value point $M \in X$

$$k(x) = \begin{cases} \dfrac{M}{2M-x}, & x \le M \\ \dfrac{x-b}{M-b}, & x \ge M \end{cases}$$

Particular case 1: when $M = b$,

$$k(x) = \begin{cases} b-x, & x > b \\ \dfrac{b}{2b-x}, & x \le b \end{cases}$$

Particular case 2: if function $k(x)$ has no maximum value at $X = (-\infty, b >$, we take $k(x) = b-x$

4. Positive field is infinite interval $X = (-\infty, +\infty),$ and max. value point $M \in X$

$$k(x) = \begin{cases} \dfrac{1}{1+M-x}, & x \le M \\ \dfrac{1}{x+1-M}, & x \ge M \end{cases}$$

Particular case: if function $k(x)$ has no maximum value at $X = (-\infty, +\infty)$, we may take $k(x) = e^x$ or $k(x) = e^{-x}$.

2.7.7 Discrete Dependent function

In many practical problems, the measured value of the study object regarding certain characteristics is discrete, for example, the product quality can be rated as excellent, good, fair, and poor; students' scores can be rated as excellent, satisfied, and unsatisfied, etc., these cases are nonnumeric discrete measurements of values. The product quality rating can also be indicated by numerical values such as 1, 2, 3, and 4, which case is numeric discrete measurement of values. In fuzzy mathematics, their values are usually given by the number between [0,1], to be used as the membership function of the study object about certain characteristic.

In Extenics, dependent function describes the degree to which the study object qualifies for certain characteristic, and it's specified that the measuring range of dependent function is $(-\infty, +\infty)$, therefore, the construction of discrete dependent function should be given value according to the degree to which the study object qualifies for certain characteristic required by the practical problem.

For example, when a company is recruiting employees, the characteristic "organizing capacity" in the recruiting conditions must reach "above good", with "fair" being the critical state. Suppose the measuring range of candidates about this characteristic is {excellent, good, fair, general, poor}, we can establish dependent function as follows:

$$k(x)=\begin{cases} 2, & x\text{=excellent} \\ 1, & x\text{=good} \\ 0, & x\text{=fair} \\ \text{-1}, & x\text{=general} \\ \text{-2}, & x\text{=poor} \end{cases}$$

When $k(x)>0$, it's considered the candidate qualifies for the characteristic of "organizing capacity"; when $k(x)<0$, it's considered the candidate does not qualify for the characteristic of "organizing capacity"; when $k(x)=0$, it's considered the candidate is in a critical state for the characteristic of "organizing capacity". In practical application, the critical state is sometimes treated as qualified, and sometimes as non-qualified.

For another example, the company's requirement for the "level of foreign language" of the candidates is "English band 4 (425 scores)", it's obvious that 425-scores is the critical condition and *x*=425 is generally considered qualified by companies, so the dependent function about this characteristic can be established as:

$$k(x)=\begin{cases} 1, & x\text{>425 scores} \\ 0, & x\text{=425 scores} \\ \text{-1}, & x\text{<425 scores} \end{cases}$$

i.e. when $k(x)\geq 0$, it's considered the candidate qualifies for the characteristic of the "level of foreign language". Of course, this characteristic can be further divided as required, such as the consideration of "English band 6", here the interested reader may independently consider establishing the corresponding dependent function.

Generally, the form of discrete dependent function is

$$k(x)=\begin{cases} A_1(>0), & x\text{=}a_1 \\ A_2(>0), & x\text{=}a_2 \\ \cdots \\ A_k(>0), & x\text{=}a_k \\ 0, & x\text{=}a_0 \\ B_1(<0), & x=b_1 \\ B_2(<0), & x=b_2 \\ \cdots \\ B_l(<0), & x=b_l \end{cases}$$

2.7.8 Logical Operation and Nature of Dependent Number

1. Logical operation of dependent number

(1) OR operation: $k_1 \vee k_2 = \max\{k_1, k_2\}$

(2) AND operation: $k_1 \wedge k_2 = \min\{k_1, k_2\}$

(3) NOT operation: $\bar{k} = -k$

2. Nature of dependent number

(1) (Commutative law) $k_1 \vee k_2 = k_2 \vee k_1$

$$k_1 \wedge k_2 = k_2 \wedge k_1$$

(2) (Absorption law) $(k_1 \vee k_2) \wedge k_2 = k_2$

$$(k_1 \wedge k_2) \vee k_2 = k_2$$

(3) (Associative law) $(k_1 \vee k_2) \vee k_3 = k_1 \vee (k_2 \vee k_3)$

$$(k_1 \wedge k_2) \wedge k_3 = k_1 \wedge (k_2 \wedge k_3)$$

(4) (Distributive law) $(k_1 \vee k_2) \wedge k_3 = (k_1 \wedge k_3) \vee (k_2 \wedge k_3)$

$$(k_1 \wedge k_2) \vee k_3 = (k_1 \vee k_3) \wedge (k_2 \vee k_3)$$

(5) (Idempotent law) $k \vee k = k$, $k \wedge k = k$

(6) (Order preserving law) if $k_1 \geq k_2$, then $k \vee k_1 \geq k \vee k_2$, $k \wedge k_1 \geq k \wedge k_2$

(7) (Duality law) $\overline{k_1 \vee k_2} = \bar{k}_1 \wedge \bar{k}_2$, $\overline{k_1 \wedge k_2} = \bar{k}_1 \vee \bar{k}_2$

2.7.9 Transformations of Dependent function

Dependent criterion is a kind of regulation on the contradiction, non-contradiction and contradictive degree of a problem. Because of this regulation, some elements cannot meet the limits, consequently causing it to be "unfeasible" and "unknowable". When a dependent criterion is changed, the elements that did not meet the original limits become the elements that meet the "new limits", consequently transforming the unfeasible to feasible, negative to positive, and unknowable to knowable. In many practical works, changing the dependent criterion is an approach to solve problems.

When introducing the types of extension transformations in 2.4 - 2.4.4 of this book, we have introduced the five basic transformations of dependent criterion. Dependent function is a quantitative expression form of dependent criterion, and the transformation of the universe of discourse and transformation of the dependent criterion will lead to the transformation of dependent function. The bibliography [2] gives the transformation of dependent function based on transformations of intervals.

1. Basic transformations of intervals

Definition 2.31 (sum and difference between interval and constant) given interval $X = <a,b>$ and constant *l*, we call $X + l = <a+l, b+l>$ the sum of the interval and the constant; and call $X - l = <a-l, b-l>$ the difference between the interval and the constant.

Definition 2.32 (multiple of interval) given interval $X = <a,b>$ and constant $\alpha > 0$, we call $\alpha X = <\alpha a, \alpha b>$ the multiple of the interval and the constant.

(1) Substitution transformation: $TX = X' = <c,d>$

Particular case: (move transformation) $T_1 X = X + l = <a+l, b+l>$

$$T_2 X = X - l = <a-l, b-l>$$

(2) Increase/decrease transformation: $T_1 X = X^{-l_1}_{+l_2} = <a-l_1, b+l_2>$,

$$T_1 X = X_{+l_2} = <a, b+l_2>,$$

$$T_1 X = X^{-l_1} = <a-l_1, b>$$

$$T_1 X = X^{+l_1}_{-l_2} = <a+l_1, b-l_2>,$$

$$T_1 X = X_{-l_2} = <a, b-l_2>,$$

$$T_1 X = X^{+l_1} = <a+l_1, b>$$

Particular case: $T_1 X = X \mp l = <a-l, b+l>, l > 0$

$$T_1 X = X \pm l = <a+l, b-l>, l > 0$$

(3) Expansion/contraction transformation: $TX = \alpha X = <\alpha a, \alpha b>$

(4) Decomposition transformation:

$$TX = \{X_1, X_2\} = \{<a,l>, <l,b>\}, \text{ where } X_1 \cup X_2 = X$$

2. Transformations of dependent function based on transformations of intervals

As to the transformations of dependent function, we should first consider the transformations of intervals, and then consider whether the optimal point of an interval after transformation is changed.

For example: as to the elementary dependent function of the optimal point reached at midpoint of interval X_0

$$k(x) = \frac{\rho(x, X)}{D(x, X_0, X)}$$

If $TX_0 = X_0' \subset X$, and the optimal point is still at the midpoint of X_0', then

$$T_k k(x) = k'(x) = \frac{\rho(x, X)}{D(x, X_0', X)}$$

If $TX = X' \supset X$, and X_0 is not changed, then

$$T_k k(x) = k'(x) = \frac{\rho(x, X')}{D(x, X_0, X')}$$

If $T_U U = U'$, then

$$T_k k(x) = k'(x) = \begin{cases} k(x) \\ k_1(x) \end{cases}$$

3. Transformations of simple dependent functions

Next we only discuss the cases when a positive field is a finite interval $X = <a, b>$, max. value point $M \in X$:

$$k(x) = \begin{cases} \dfrac{x-a}{M-a}, & x \le M \\ \dfrac{b-x}{b-M}, & x \ge M \end{cases}$$

a)Move transformation: $k'(x+l) = k(x)$, or $k'(x) = k(x-l)$

b) Expansion/Contraction transformation: $k'(\alpha x) = k(x)$, or $k'(x) = k(\frac{x}{\alpha})$

c) Substitution transformation: $TX = X' =< c, d >$

$$k'(\frac{d-c}{b-a}x + \frac{bc-ad}{b-a}) = k(x), \text{ or } k'(x) = k[(x - \frac{bc-ad}{b-a})\frac{b-a}{d-c}]$$

d)Increase/Decrease transformation: adding to the right $T_1 X = X_{+l_2} =< a, b + l_2 >$,

$$k'(\frac{l_2 + b - a}{b-a}x - \frac{al_2}{b-a}) = k(x), \text{ or } k'(x) = k[(x + \frac{al_2}{b-a})\frac{b-a}{l_2 + b - a}]$$

e) Decomposition transformation: $k(x) = \{k_1(x), k_2(x)\}$

2.8 Brief Introduction to Extension Logic

It's shown by the study on Extenics that, in the practical activities of human beings, many contradictory problems are not unsolvable, but can be solved by multiple methods. Therefore, we must study the logic that solves contradictory problems or helps us treat contradictory problems by using computers.

Extension logic [6] is the science that studies the transformation and reasoning laws that change contradictory problems into non-contradictory problems. It's the third pillar proposed after the basic-element theory and the extension set theory in Extenics. It's the logic difference from mathematical logic and fuzzy logic.

Extension reasoning, as one of the main contents of extension logic, will provide new reasoning technology for solving contradictory problems by computers. The study on extension reasoning is very preliminary, especially the study on conductive reasoning and conjugate reasoning of compound-element transformations, etc., should be further deepened, only by which can we achieve the goal of computerization of extension methods.

This section briefly introduces the nature, characteristics and simple reasoning of extension logic.

2.8.1 Characteristics of Extension Logic

1. Study on the Logic that transforms contradictory problems

Mathematic logic mainly studies the logic without contradictory premise. However, we have to deal with contradictions and treat various contradictory problems in our daily life. Therefore, we should not only study non-contradictory logic, but also study the logic with contradictory premise. Extension logic is the very logic that studies how to transform contradictory problems into non-contradictory problems. In other words, it studies how to obtain non-contradictory conclusions through certain transformations on the contradictory premise.

Mathematic logic studies the reasoning laws in classical mathematics, fuzzy logic studies the reasoning laws in fuzzy mathematics, while extension logic studies the transformation and reasoning laws in Extenics. Because the classical mathematics studies definite problems, fuzzy mathematics studies fuzzy problems, while Extenics studies contradictory problems, the contents studied by corresponding logics varies with different study objects.

2. Logical values that change with transformation

In classical logic, whether an object that has certain nature is determined only by "yes" or "no"; whether a proposition that is correct is determined only by "true" or "false", i.e. the characteristic function value is determined only by 0 or 1. In fuzzy logic, the membership function value is determined by the real number in [0, 1]. In extension logic, the real number taken from $(-\infty, +\infty)$ is used to describe the degree of "yes" or "no" and "true" or "false". This kind of degree may be positive or negative, with positive values indicating the degree of "yes" or "true", and negative values indicating the degree of "no" or "false". Thus, "there is the same within the class and there are differences among classes" is developed to "there are also differences within the class", i.e. there are differences of degrees within the class.

In classical logic and fuzzy logic, as to whether an object has certain nature, the proposition of "true" or "false" is relatively fixed, but in extension logic, because of the introduction of transformations (including the changes of time and space), the degree that an object has certain nature and the degree of the proposition of "true/false" changes with transformations. It can be said that the classical logic and fuzzy logic study the nature of objects and truthfulness/falseness of propositions from the "static" angle; extension logic discusses the degree that an object has certain nature and the change of truthfulness/falseness of proposition from the "transformational" angle.

3. Combination of formal logic and dialectic logic

"The philosophy of traditional noun logic uses nonempty and non-full classes as the point of view to understand the world, which only pays attention to the relation between classes, but ignores the individuals that constitute the class, and ignores the relation between the individuals. Predicate logic uses individuals as the point of view to understand the world and uses all individuals in certain universes of discourse as objects, to study their general nature and relations, and to achieve the goal of understanding the world, which is the philosophy of predicate logic." [14] Extension logic uses the characteristics and structure of individuals as the point of view to understand the world, and uses basic-elements as the description tool to study their general nature and relations, to achieve the goal of understanding the world. Therefore, extension logic studies not only class and individuals, but also the characteristics of individuals and the structure of conjugate parts, i.e. studies the matter-element, affair-element, relation-element and conjugate parts.

To study the reasoning of "changes", extension logic must comply with the fundamental laws of natural dialectics. Therefore, extension logic also uses symbols to express certain laws of dialectic logic, for easy manipulation and operation of these laws, and let dialectic logic not stay only at the description of natural language.

It can be said that extension logic absorbs the formalized characteristics of formal logic, and adopts the thinking of connotation study of dialectic logic, combined and developed to the logic that transforms contradictory problems.

2.8.2 Study Content of Extension Logic

1. Establishment of the logic for formalized expression of quantitative and qualitative changes

The description of precise objects by binary logic is extremely meaningful. For example, the majority in lifeless mechanical systems are objects with distinct boundaries, which comply with the fundamental laws of binary logic–the law of identity, the law of contradiction and the law of excluded middle, and allow us to make judgments that comply with these three laws. But in the ever-developing management science, social science, life science and thinking science, these three major laws limits the application of binary logic in these sciences. In 1965, L. A. Zadeh proposed and clarified the concept of fuzzy set, changed the traditional thinking method that repels fuzziness and unilaterally pursued accuracy, which has unified the scientific community for thousands of years, and introduced fuzziness into mathematics.

However, no matter whether it is binary logic or fuzzy logic, they lay particular emphasis on the static status in the study on the nature of objects, and generally consider the degree that an object has certain nature as being unchangeable. To solve contradictory problems, certain transformations must be discussed, in order to change the degree that an object has certain nature, and consequently transform the involved problem from being incompatible to compatible and from being antithetic to coexistent. In other words, to study how to transform the infeasible to feasible, unknowable to knowable, false to true, and wrong to correct, we must establish the logic that can express quantitative and qualitative changes.

2. From a study on static proposition to a study on changeable proposition

The consideration of proposition by traditional method only studies whether it's true or false. Actually, truthfulness and falseness may be different in degree, and the true proposition in certain conditions may be false in another condition. Contrarily, the false proposition in certain conditions may be true in other conditions. Therefore, in solving contradictory problems, the judgment that the object is true or false is changeable, and the truthfulness and falseness in certain transformations may undergo quantitative change, and qualitative change if developed to a certain degree. That's to say, we should study the problem that the proposition is true in certain conditions. Similarly, the correctness of reasoning is also conditional. In certain conditions, wrong reasoning may be transformed to correct reasoning; contrarily, in certain conditions, correct reasoning may be transformed to wrong reasoning. Therefore, we should study the function of transformation on the truthfulness of proposition or correctness of reasoning, in other words, the static study on proposition and reasoning should be expanded to changeable study.

3. Study on the logic that involves the connotation of objects

To study, the solving method and process of the contradictory problem, only considering the formalized deduction of concept is not enough. For example, in the story of Cao Chong Weighs the Elephant, the key for solving the problem is to transform the undividable elephant into dividable stones, which, however, is not considered in formal logic that excludes the connotation of objects and only makes formal deduction, but solving the contradictory problem involves the connotation and changes of an object, which is the content considered by dialectic logic. However, dialectic logic is expressed in natural language. To establish the logic that can solve the contradictory problem, it must have both the advantage of formalization of formal logic and the function of describing the connotation of an object.

4. Study on the logic that describes both "yes" and "no"

A cabinet that is too high to be moved through the door can be moved in by the method of "putting it down". Here, the put-down cabinet is both the original cabinet and not the original cabinet. Water contains too many impurities to be used in the chemical test, while the contradictory problem of containing too many impurities is solved by the method of distillation. The measures of certain characteristics of the distilled water are the same as the original water, while some characteristics, such as the content of impurities, are changed. In the process of solving contradictory problems, this kind of treating method of "both being it and not being it" can be found everywhere, but these phenomena are not, or cannot be studied by binary logic or fuzzy logic. Therefore, we must establish the logic that can describe these phenomena.

In summary, by combining formal logic and dialectic logic together, the study on new logic to solve contradictory problems is one of the basic theories on the solution to contradictory problems.

2.8.3 Extension Reasoning

The existing binary logic and fuzzy logic that mainly describe definite and fuzzy objects cannot be used as the tool for solving contradictory problems. Therefore, the logic that is applicable for solving contradictory problems must be established, to let transformation and reasoning no longer stay on the traditional basis of definiteness and fuzziness, but be capable for studying and describing the transformation and reasoning of the changeability of objects, and let them become the basic theory for computers to conduct creative thinking and propose the strategy to solve contradictory problems in the future.

The study on extension theory in its preliminary stage focused on the establishment of formalized models, proposed the concepts of matter-element, affair-element and relation-element, etc., and established the extension model, extension set, dependent function, and other quantitative tools. As the theory developed to now, its focus should be transformed from establishing models to the study on "transformation" and "reasoning". On the other hand, the study on application of Extenics is relatively preliminary, and many scholars feel “lack of tools”, which urgently demands the researchers of extension theory to study the “logic” tools that are particular to Extenics. It can be seen that, no matter whether you are embarking from the study on extension theory or considering its application study, the discussion of transformation and reasoning forms that comply with the extension thinking mode will inevitably become one of the key points in the future study on Extenics.

In order to use formalized methods to study the solution to contradictory problems and consequently to help to solve contradictory problems by the aid of a computer, reference [6] studied the extension logic and established the law of extension reasoning. Transformation and extension reasoning, as the core in solving contradictory problems, will provide new reasoning technology for artificial intelligence, and new methods for solving problems.

This section briefly introduces the basic contents of extension reasoning, including expansible reasoning, conductive reasoning and conjugate reasoning.

1. Basic-element extensible reasoning

Basic-element extensible reasoning includes basic-element divergence reasoning, basic-element implication reasoning, basic-element correlation reasoning, and basic-element opening-up reasoning. It’s specified in this section that “A—|B” indicates “B can be diverged from A”; “$A \models B$” indicates “B can be derived from A”.

(1) Basic-element divergence reasoning

Divergence rule 2.1 Given basic-element $B=(O, c, v)$, we have

$$B \dashv \{ B_i \mid B_i =(O, c_i, v_i) ,i=1,2,\ldots,n, c_i \in £(c)\}$$

$$B \dashv \{ B_i \mid B_i =(O_i, c, v_i) , i=1,2,\ldots,n, c \in £(c)\}$$

$$B \dashv \{ B_i \mid B_i =(O_i, c_i, v) , i=1,2,\ldots,n , c_i \in £(c)\}$$

$$B \dashv \{ B_i \mid B_i =(O_i, c, v) , i=1,2,\ldots,n , c \in £(c)\}$$

$$B \dashv \{ B_i \mid B_i =(O, c_i, v) , i=1,2,\ldots,n, c_i \in £(c) \}$$

$$B \dashv \{ B(t) \mid B(t)=(O(t), c, v(t)) , t \text{ is certain parameter}\}$$

Suppose $B_1=(O_1, c_1, v_1)$, c_{01} as the evaluation characteristic of the basic-element, measure $c_{01}(B_1)=x$, $V(c_{01})$ as its measure range, X_0 as its positive domain, $X_0 \subset V(c_{01})$, and established dependent function as $K_1(B_1)= k_1(c_{01}(B_1)) = k_1(x)$, then we have the following divergence rules:

Divergence rule 2. 2 if

$$B_1 —| \{ B_i=(O_1, c_i, v_i), i=1,2,\ldots,n\}$$

then c_{01}—| $\{c_{01}, c_{02}, \ldots, c_{0m}\}$. Wherein $c_{0j}(j=2,3,\ldots,m)$ indicates new evaluation characteristics.

In particular, if c_j is the characteristic with the same domain of c_1, i.e. B_j is the basic-element with the same object and same domain of B_1, we may have $c_{0j}= c_{01}$.

Divergence rule 2. 3 if c_{01}—| $\{c_{01}, c_{02}, \ldots, c_{0m}\}$, then

$$k_1(c_{01}(B_1))—\!\!\mid \begin{pmatrix} k_1(c_{01}(B_1)) \\ k_2(c_{02}(B_1)) \\ \vdots \\ k_m(c_{0m}(B_1)) \end{pmatrix}$$

Divergence rule 2. 4 If B_1—| $\{B_i=(O_1, c_i, v_i), i=1,2,\ldots,n\}$, and c_{01}—| $\{c_{01}, c_{02}, \ldots, c_{0m}\}$, then

$$k_1(c_{01}(B_1))—\!\!\mid \begin{bmatrix} k_1(c_{01}(B_1)) & k_1(c_{01}(B_2)) & \cdots & k_1(c_{01}(B_n)) \\ k_2(c_{02}(B_1)) & k_2(c_{02}(B_2)) & \cdots & k_2(c_{02}(B_n)) \\ \vdots & \vdots & \cdots & \vdots \\ k_m(c_{0m}(B_1)) & k_m(c_{0m}(B_2)) & \cdots & k_m(c_{0m}(B_n)) \end{bmatrix}$$

Divergence rule 2.5

1) If $B_1=(O_1, c, v)$—|$\{B_i=(O_i, c, v), i=1,2,\ldots,n\}$, then

$$k_1(c_{01}(B_1))—\!\!\mid \{k_1(c_{01}(B_1)), k_1(c_{01}(B_2)), \cdots, k_1(c_{01}(B_n))\}$$

2) In 1), if c_{01}—| $\{c_{01}, c_{02}, \ldots, c_{0m}\}$, then

$$\{k_1(c_{01}(B_1)), k_1(c_{01}(B_2)), \cdots, k_1(c_{01}(B_n))\}$$

$$—\!\!\mid \begin{bmatrix} k_1(c_{01}(B_1)) & k_1(c_{01}(B_2)) & \cdots & k_1(c_{01}(B_n)) \\ k_2(c_{02}(B_1)) & k_2(c_{02}(B_2)) & \cdots & k_2(c_{02}(B_n)) \\ \vdots & \vdots & \cdots & \vdots \\ k_m(c_{0m}(B_1)) & k_m(c_{0m}(B_2)) & \cdots & k_m(c_{0m}(B_n)) \end{bmatrix}$$

(2) Basic-element implication reasoning

On the universe of discourse of basic-elements $W(B)$, establish extension set of basic-elements $\tilde{E}(B)(T)$, with a dependent function of $y=K(B)=k(c_0(B))$, c_0 as an evaluation characteristic of basic-elements, and $B_1, B_2, B_3 \in W(B)$, then we have the following implication rules:

Implication rule 2.6 if $B_2 \Rightarrow B_1$, then $(K(B_1)\le 0) \;|= (K(B_2)\le 0)$

Implication rule 2.7 if $B_1 \wedge B_2 \Rightarrow B$, then $(K(B)\le 0) \;|= ((K(B_1)\le 0) \vee (K(B_2)\le 0))$.

Implication rule 2.8 if $B_1 \vee B_2 \Rightarrow B$, then $(K(B)\le 0) \;|= ((K(B_1)\le 0) \wedge (K(B_2)\le 0))$.

Implication rule 2.9 $((B_1 \Rightarrow B_3) \wedge (B_2 \Rightarrow B_3)) \;|= ((B_1 \vee B_2) \Rightarrow B_3)$;

$((B_1 \Rightarrow B_2) \wedge (B_2 \Rightarrow B_3)) \;|= (B_1 \Rightarrow B_3)$;

$((B_1 \Rightarrow B_2) \wedge (K(B_1)\ge 0)) \;|= (K(B_2)\ge 0)$;

$((B_1 \Rightarrow B_2) \wedge (K(B_2)\le 0)) \;|= (K(B_1)\le 0)$.

(3) Basic-element correlation reasoning

Supposing c_0 is an evaluation characteristic of basic-elements, on the universe of discourse $W(B)$, establish extension set of basic-elements $\tilde{E}(B)(T)$, with its dependent function of $y=K(B)=k(c_0(B))$, then we have the following correlation rules:

Correlation rule 2.10 suppose $\{B_1\}=\{(O_1, c_1, v_1)\}$, $\{B_2\}=\{(O_2, c_2, v_2)\}$, $\{B_1\},\{B_2\}\subset W(B)$, then

$$(\{B_1\}\sim\{B_2\}) \models (\exists f \; , c_0(B_2)=f(c_0(B_1)), \text{or } c_0(B_1)=f(c_0(B_2)))$$

wherein $B_1\in\{B_1\}, B_2\in\{B_2\}$.

Correlation rule 2.11 suppose $\{B_i\}=\{(O_i, c_i, v_i), \quad i=1,2,3\}$, then

$$((\{B_1\}\sim\{B_2\})\wedge(\{B_2\}\sim\{B_3\}))$$

$$\models \{B_1\}\sim\{B_3\}$$

$$\models (\exists f \; , c_0(B_3)=f(c_0(B_1)) \;)$$

wherein $B_1\in\{B_1\}, B_3\in\{B_3\}$.

(4) Basic-element opening-up reasoning

Supposing c_0 is an evaluation characteristic of basic-elements, on the universe of discourse $W(B)$, establish extension set of basic-elements $\tilde{E}(B)(T)$, with its dependent function of $y=K(B)=k(c_0(B))$, then we have the following opening-up rules:

Opening-up rule 2.12 suppose $B=(O, c, v)\in£(B) \quad |= \quad \exists \; B_1=(O_1, c_1, v_1)$, to let

$$B\oplus B_1=\begin{bmatrix} O\oplus O_1, & c, & v\oplus c(O_1) \\ & c_1, & v_1\oplus c(O) \end{bmatrix}.$$

Opening-up rule 2.13 suppose c_0 is an evaluation characteristic of basic-elements,

$$B\oplus B_1=\begin{bmatrix} O\oplus O_1, & c, & v\oplus c(O_1) \\ & c_1, & v_1\oplus c(O) \end{bmatrix}, c_0 \text{—|} \{c_0, c_{01}\}, \text{ then}$$

$$c_0(B) \text{—|} \begin{pmatrix} c_0(B\oplus B_1) \\ c_{01}(B\oplus B_1) \end{pmatrix}$$

and

$$k(c_0(B)) \text{—|} \begin{pmatrix} k(c_0(B\oplus B_1)) \\ k_1(c_{01}(B\oplus B_1)) \end{pmatrix}$$

Opening-up rule 2.14 $(\forall B=(O, c, v)\in £(B)) \quad |= (\exists\alpha, \; B'=B\alpha=(O', \; c, \; \alpha v), \alpha v=c(O'))$.

Opening-up rule 2.15 suppose c_0 is an evaluation characteristic of basic-elements, B—$|B\alpha$, c_0—$|\{c_0, c_{01}\}$, then

$$c_0(B) \dashv \begin{pmatrix} c_0(\alpha B) \\ c_{01}(\alpha B) \end{pmatrix}$$

and

$$k(c_0(B)) \dashv \begin{pmatrix} k(c_0(\alpha B)) \\ k_1(c_{01}(\alpha B)) \end{pmatrix}$$

Opening-up rule 2.16 suppose B=(O, c, v)∈ £(B) , if $B/\{B_1, B_2, \cdots, B_n\}$, and c_0 is an evaluation characteristic of basic-elements, and

$$c_0 \dashv \{c_0, c_{02}, \ldots, c_{0m}\}$$

then

$$c_0(B) \dashv \begin{bmatrix} c_0(B_1) & c_0(B_2) & \cdots & c_0(B_n) \\ c_{02}(B_1) & c_{02}(B_2) & \cdots & c_{02}(B_n) \\ \vdots & \vdots & \vdots & \vdots \\ c_{0m}(B_1) & c_{0m}(B_2) & \cdots & c_{0m}(B_n) \end{bmatrix}$$

$$k(c_0(B)) \dashv \begin{bmatrix} k_1(c_0(B_1)) & k_1(c_0(B_2)) & \cdots & k_1(c_0(B_n)) \\ k_2(c_{02}(B_1)) & k_2(c_{02}(B_2)) & \cdots & k_2(c_{02}(B_n)) \\ \vdots & \vdots & \vdots & \vdots \\ k_m(c_{0m}(B_1)) & k_m(c_{0m}(B_2)) & \cdots & k_m(c_{0m}(B_n)) \end{bmatrix}$$

2. Conductive reasoning of basic-element transformation

Conductive reasoning refers to the reasoning of conductive transformation with extension transformation as antecedent and its caused conductive transformation as consequences. In terms of its content, conductive reasoning is divided into two aspects of qualitative part and quantitative logical change. Considering from the main body of transformation, conductive reasoning can be divided into two types of independent conductive reasoning and dependent conductive reasoning, while the independent conductive reasoning can be further divided into substitution conductive reasoning, increasing/decreasing conductive reasoning, expansion/contraction conductive reasoning, and decomposition conductive reasoning. Considering from the object of transformation, conductive reasoning can be divided into the conductive reasoning of matter-element transformation, conductive reasoning of affair-element transformation, and conductive reasoning of relation-element transformation.

(1) Independent conductive reasoning

The independent conductive reasoning rule is the reasoning rule of conductive transformation of basic-elements and the dependent degree of basic-elements caused by conductive transformation of a key element that is led by the change of another certain key element inside the basic-element.

Conductive rule 2.17 $({T_O}\, O{=}O') \models ({}_O T_v v = v')$

$$\models ({}_{(O,v)}T_B\, B{=}(O', c, v') = B')$$

$$\models (K({}_{(O,v)}T_B\, B) = k(c_0(B')))$$

Conductive rule 2.18 $(T_O O{=}O \oplus O')$

$$\models ({}_O T_v v = v' = c\,(O \oplus O'))$$

$$\models ({}_{(O,v)}T_B\, B{=}(O \oplus O', c, c\,(O \oplus O')) = B')$$

$$\models (K({}_{(O,v)}T_B\, B) = k(c_0(B')))$$

Conductive rule 2.19 $(T_v\, v{=}\alpha v)$, wherein, $\alpha \in <0,+\infty>$

$$\models ({}_v T_O O = O')$$

$$\models ({}_{(v,O)}T_B B = (O, c, \alpha v) = B')$$

$$\models (K({}_{(v,O)}T_B B) = k(c_0(B')))$$

When $\alpha>1$, this rule is the conductive rule of expansion transformation of basic-element, and when $0<\alpha<1$, it's the conductive rule of contraction transformation of a basic-element.

Conductive rule 2.20 $(T_O O{=}\{O_1, O_2, \ldots, O_n\})$

$$\models ({}_O T_B B{=}\{(O_1, c, c(O_1)), (O_2, c, c(O_2)), \ldots, (O_n, c, c(O_n))\}$$

$$=\{B_1, B_2, \ldots, B_n\})$$

$$\models (K({}_O T_B B) = \{k(c_0(B_1)),\ k(c_0(B_2)), \ldots, k(c_0(B_n))\})$$

(2) Dependent conductive reasoning

Transformation of a basic-element may cause conductive transformation of its related basic-elements, and cause changes to the dependent degrees on the related basic-elements, which is referred to as the dependent conductive reasoning rule.

Conductive rule 2.21 if $\{B_1\},\{B_2\} \subset W(B)$, $\{B_1\} \sim \{B_2\}$, $c_0(B_2){=}f(c_0(B_1))$, then

$$(T_{B_1} B_1{=}B_1') \models ({}_{B_1}T_{B_2} B_2{=}B_2')$$

$$|= (K({}_{B_1}T_{B_2}\, B_2)= K(B_2')=k[(c_0(B_2'))] =k[f(c_0(B_1'))])$$

wherein $B_1, B_1' \in \{B_1\}, B_2, B_2' \in \{B_2\}$.

3. Conductive reasoning of compound-element transformation

The basis for conductive reasoning of compound-element transformation is the extensibility of compound-elements and conductibility of the compound-element transformation. The study method is similar to the conductive reasoning of basic-element transformation.

In the compound-element composed of matter-element, affair-element and relation-element, the transformation of certain key elements will cause changes of corresponding compound-elements, which also complies with the theory of “moving the whole body by pulling one hair”. Therefore, many people of wisdom and vision have designed various marvelous strategies and clever ideas by utilizing this kind of conductive transformation, to treat various contradictory problems. Space lacks introduction to the conductive reasoning rule of compound-element transformation.

4. Conjugate reasoning

It’s known from the conjugate analysis of objects that any object has four pairs of conjugate parts. In certain conditions, changes within certain conjugate parts of an object will cause conductive transformations of the corresponding part that is related with it.

Conjugate reasoning includes conductive reasoning of conjugate rules and conjugate part basic-element transformations, and conductive reasoning of conjugate part transformations.

As to an object O_m, its conjugate parts are denoted respectively as im(O_m) and re(O_m), sf(O_m) and hr(O_m), lt(O_m) and ap(O_m), ng$_c$(O_m) and ps$_c$(O_m). Only the conductive reasoning rules of transformations of real part and imaginary part matter-elements are given in the following, to which other rules are similar.

Conductive rule 2.22 **S**uppose $\hat{M}_{\text{re}} = (\text{re}(O_m), \hat{c}_{\text{re}}, \hat{v}_{\text{re}})$ and $\hat{M}_{\text{im}} = (\text{im}(O_m), \hat{c}_{\text{im}}, \hat{v}_{\text{im}})$ are respectively imaginary and real matter-elements, then

$$(\varphi\hat{M}_{\text{re}} = \hat{M}'_{\text{re}}) \models ({}_{\varphi}T_{\text{im}}\hat{M}_{\text{im}} = \hat{M}'_{\text{im}})$$

Instruction: φ in this rule represents the active transformation of the real part matter-element, i.e. $\varphi = T_{\hat{M}_{\text{re}}}$, ${}_{\varphi}T_{\text{im}}$ indicates the conductive transformation caused by transformation φ, i.e. ${}_{\varphi}T_{\text{im}} = {}_{\hat{M}_{\text{re}}}T_{\hat{M}_{\text{im}}}$. For easy writing, the following rules also adopt the symbols in this rule.

Conductive rule 2.23 **S**uppose M_{re}=(re(O_m), c_{re}, v_{re}) is certain real part matter-element, M_{im}=(im(O_m), c_{im}, v_{im}) is certain imaginary part matter-element, $\hat{M}_{\text{re}} = (\text{re}(O_m), \hat{c}_{\text{re}}, \hat{v}_{\text{re}})$ and $\hat{M}_{\text{im}} = (\text{im}(O_m), \hat{c}_{\text{im}}, \hat{v}_{\text{im}})$ are imaginary and real conjugate matter-elements, then

$$((\varphi M_{\text{re}}=M'_{\text{re}})\wedge(M_{\text{re}}\sim M_{\text{im}})) \models ({}_{\varphi}T_{\text{im}}\, M_{\text{im}}=M'_{\text{im}})$$

$((\varphi M_{re}=M'_{re})\wedge(M_{re}\sim \hat{M}_{re})) \models ({}_{\varphi}T_{re}\hat{M}_{re}=\hat{M}'_{re}) \models ({}_{\varphi'}T_{im}\hat{M}_{im}=\hat{M}'_{im})$, wherein $\varphi' = {}_{\varphi}T_{re}$

$((\varphi M_{im}=M'_{im})\wedge(M_{re}\sim M_{im})) \models ({}_{\varphi}T_{re}\, M_{re}=M'_{re})$

$((\varphi M_{im}=M'_{im})\wedge(Mc_{im}\sim \hat{M}_{im})) \models ({}_{\varphi}T_{im}\hat{M}_{im}=\hat{M}'_{im}) \models ({}_{\varphi''}T_{re}\hat{M}_{re}=\hat{M}'_{re})$, wherein $\varphi'' = {}_{\varphi}T_{im}$

2.8.4 Extension Proposition and Extension Reasoning Sentence

The study on extension logic is a basic work to change the theory and methods of Extenics theory to computer algorithm and to be realized in computers. The traditional logic studies whether the proposition is true or false and whether the reasoning is correct or wrong. In the real world, that the proposition is true or false is conditional, and the truthfulness/falseness of the same proposition may be different in different conditions. For example, in Euclidean Geometry, "the triangle interior angle summation equals to 180^0" is correct, while in spherical geometry, this proposition is incorrect. Likewise, that the reasoning is correct or wrong is also conditional. Therefore, we should not only study whether the proposition is true or false and the reasoning is correct or wrong, but also study what are the conditions for transformation from true to false and from correct to wrong, or study what transformations should be adopted to transform false to true and wrong to correct.

Reference [6] gives the concepts of proposition truthfulness and reasoning sentence correctness by utilizing the concept of extension set. On this basis, reference [15] gives the concepts of extension truthfulness of proposition and extension correctness of reasoning sentence, introduced the concepts of static truthfulness, extension truthfulness, static correctness and extension correctness, and studies the relevant nature of proposition truthfulness and reasoning sentence correctness. The obtained results improved and enriched the study achievement on proposition and reasoning sentence in reference [6].

1. Extensible proposition and extensible reasoning sentence

Definition 2.33 The proposition expressed by matter-element is referred to as matter-element proposition; the proposition expressed by affair-element is referred to as affair-element proposition; the proposition expressed by relation-element is referred to as relation proposition, all of which are collectively referred to as basic-element propositions.

Similarly, the reasoning sentence: $(a)\rightarrow(b)$ can also be expressed by basic-elements as $B_a \models B_b$, referred to as a basic reasoning sentence. Where, the basic-element B_a that indicates (a) is referred to as an antecedent basic-element; B_b that indicates (b) is referred to as a consequent basic-element.

After proposition is expressed by basic-elements, the transformation of a basic-element and its operation can describe the transformation and its operation of corresponding proposition; according to the extensible reasoning rule of basic-elements, the obtained new proposition is referred to as the extensible proposition of the original proposition. After reasoning sentence is expressed by basic-elements, according to the extensible reasoning rule of basic-elements, many new reasoning sentences can be extended, referred to as the extensible reasoning sentence of the original reasoning sentence.

2. Truthfulness of proposition and correctness of reasoning sentence

In mathematic logic, two numbers of 0 and 1 are used for the qualitative description of the truthfulness and falseness of propositions and correctness and wrongfulness of reasoning sentences. But in the real world, the truthfulness and falseness of propositions and correctness and wrongfulness of reasoning sentences are different in degree, and the quantitative description of the degrees of truthfulness/falseness and correctness/wrongfulness and their variations usually must be studied as well. The dependent function in extension set can be used as the quantitative tool for describing this kind of degree. According to the definition of extension set given in 2.6, the concept that describes the degree of truthfulness/falseness of proposition is given as follows.

Definition 2.34 Given proposition set of basic-elements

$$W=\left\{B \middle| B=(O,c,v),O\in U,v\in V(c)\right\}$$

with c_0 as the evaluation characteristic of *B*, the extension set of basic-elements established on *W*

$$\tilde{E}(B)(T)=\Big\{(B,y,y')\Big|B\in W,\ y=K(B)=k\big(c_0(B)\big);$$

$$T_B B\in T_W W,\ y'=K'(B,T)=T_K K(T_B B)=T_k k\big(c_o(T_B B)\big)\ \Big\}$$

We call $y=K(B)$ the static truthfulness of proposition *B*, $y'=K'(B,T)$ the extension truthfulness of proposition *B* under transformation *T*, where transformation $T=(T_W,T_K,T_B)$.

Instructions: (1) In Definition 2.34, the static truthfulness $y=k(B)$ scores the degree how proposition *B* complies with the objective reality, i.e. the degree of truthfulness/falseness of proposition *B*; the extension truthfulness $y'=k'(B,T)$ scores the degree of truthfulness/falseness of the extensible proposition of the original proposition *B* under transformation *T*.

(2) Static truthfulness $y=K(B)>0$ indicates that proposition *B* is a true proposition; $y=K(B)<0$ indicates that proposition *B* is a false proposition; $y=K(B)=0$ indicates that proposition *B* is both true and false. Similarly, the extension truthfulness $y'=K'(B,T)>0$ indicates that the extensible proposition of proposition *B* under transformation *T* is a true proposition; $y'=K'(B,T)<0$ indicates that the extensible proposition of proposition *B* under transformation *T* is a false proposition. $y'=K'(B,T)=0$ indicates that the extensible proposition of proposition *B* under transformation *T* is both true and false.

(3) If $K(B)K'(B,T)\le 0$, it indicates transformation *T* caused a qualitative change of the truthfulness/falseness of proposition *B*, now we call *T* the qualitative transformation of *B* about truthfulness; if $K(B)K'(B,T)\ge 0$, it indicates transformation *T* only caused quantitative changes of the truthfulness/falseness of proposition *B*, now we call *T* the quantitative transformation of *B* about truthfulness.

The following natures can be easily obtained from Definition 2.34:

Nature 2.3 If $B\in \underset{\bullet}{E}_+(T)$, then transformation *T* changes the false proposition *B* to true proposition; if $B\in \underset{\bullet}{E}_-(T)$, then transformation *T* changes the true proposition *B* to false proposition.

Similarly, we give the concept that describes the degree of correctness/wrongfulness of reasoning sentences as follows.

Definition 2.35 Given reasoning sentence set of basic-elements

$$W=\left\{F \middle| F:l\models g,\ \ l\in\{L\},g\in\{G\}\ \right\}$$

with c_0 as an evaluation characteristic, we make extension set of basic-elements on *W*

$$\tilde{E}(F)(T)=\{(F,y,y')|F\in W, y=K(F)=k(c_0(F));$$

$$T_F F\in T_W W, y'=K'(F,T)=T_K K(T_F F)=T_k k(c_0(T_F F))\ \}$$

We call $y=K(F)$ the static correctness of reasoning sentence *F*, $y'=K'(F,T)$ the extension correctness of reasoning sentence *F* under transformation *T*, and $\tilde{E}(T)(F)$ the extension set of reasoning sentence of basic-elements on *W*, where transformation $T=(T_W,T_K,T_F)$.

As to certain concepts and conclusions of proposition truthfulness, the correctness translated to reasoning sentence is also sustainable, which is not described in detail herein.

3. Truthfulness of logical operation of proposition and correctness of logical operation of reasoning sentence

First, we discuss the natures that are related to the truthfulness of logical operation of proposition. Because of the nature of dependent function, the following natures can be easily known:

Nature 2.4 Suppose $\tilde{E}(B)(T)$ is an extension set of propositions of basic-elements on *W*, *K*(*B*) and $K'(B,T)$ are respectively static truthfulness and extension truthfulness of *B*, and suppose $B_1, B_2 \in W$, then

$$K(B_1\vee B_2)=K(B_1)\vee K(B_2),\quad K'(B_1\vee B_2,T)=K'(B_1,T)\vee K'(B_2,T)$$

$$K(B_1\wedge B_2)=K(B_1)\wedge K(B_2),\quad K'(B_1\wedge B_2,T)=K'(B_1,T)\wedge K'(B_2,T)$$

Nature 2.5 Suppose $\tilde{E}(B)(T)$ is extension set of propositions of basic-elements on *W*,

(1) if $B_1,B_2\in \underset{\bullet}{E}_+(T)$, then $B_1\vee B_2,\ B_1\wedge B_2\in \underset{\bullet}{E}_+(T)$;

(2) if $B_1,B_2\in \underset{\bullet}{E}_-(T)$, then $B_1\vee B_2,\ B_1\wedge B_2\in \underset{\bullet}{E}_-(T)$;

(3) if $B_1\in \underset{\bullet}{E}_+(T)$, $B_2\in \underset{\bullet}{E}_-(T)$, then $B_1\vee B_2\in E_+(T)$, $B_1\wedge B_2\in E_-(T)$

It's proved: (1) because $B_1,B_2\in \underset{\bullet}{E}_+(T)$, so

$$K(B_1)\le 0,\ K'(B_1,T)>0;\ K(B_2)\le 0,\quad K'(B_2,T)>0$$

It can be known from Nature 2.4

$$K(B_1\vee B_2)=K(B_1)\vee K(B_2)\le 0$$

$$K(B_1\wedge B_2)=K(B_1)\wedge K(B_2)\le 0$$

$$K'(B_1\vee B_2,\ T)=K'(B_1,\ T)\vee K'(B_2,\ T)>0$$

$$K'(B_1\vee B_2,\ T)=K'(B_1,\ T)\vee K'(B_2,\ T)>0$$

So

$$B_1\vee B_2\in \underset{\bullet}{E}_+(T),\quad B_1\wedge B_2\in \underset{\bullet}{E}_+(T)$$

Similarly (2) and (3) can be also proved sustainable.

It's shown by Nature 2.5 that, the propositions in the positive (negative) extension field after "OR"/"AND" operation remain the propositions in the positive (negative) extension domain, here the qualitative transformation T remains qualitative transformation after the "OR"/"AND" operation of the two propositions; while the proposition in the positive extension field and the proposition in the negative extension field after the "OR"/"AND" operation are changed to propositions in stable field, here the qualitative transformation T is changed to quantitative transformation after the "OR"/"AND" operation of the two propositions.

In summary, if T is qualitative transformation of B_1 and B_2 about truthfulness, it cannot be determined that T is qualitative transformation of $B_1 \vee B_2$ or $B_1 \wedge B_2$. Similarly, if T is quantitative transformation of B_1 and B_2 about truthfulness, it also cannot be determined that T is quantitative transformation of $B_1 \vee B_2$ or $B_1 \wedge B_2$. The study on qualitative transformation and quantitative transformation or truthfulness of proposition in extension logic is an extremely meaningful work.

Similarly, we give the natures that are related to the correctness of logical operation of reasoning sentence as follows:

Nature 2.6 Suppose $\tilde{E}(F)(T)$ is an extension set of reasoning sentences of basic-elements on W, $K(F)$ and $K(F, T)$ are respectively the static correctness and extension correctness of F, and suppose $F_1, F_2 \in W$, then

$$K(F_1 \vee F_2) = K(F_1) \vee K(F_2),\quad K'(F_1 \vee F_2, T) = K'(F_1, T) \vee K'(F_2, T)$$

$$K(F_1 \wedge F_2) = K(F_1) \wedge K(F_2),\quad K'(F_1 \wedge F_2, T) = K'(F_1, T) \wedge K'(F_2, T)$$

Nature 2.7 Suppose $\tilde{E}(F)(T)$ is an extension set of reasoning sentences of basic-elements in W

(1) if $F_1, F_2 \in \underset{\bullet}{E}_+(T)$, then $F_1 \vee F_2, F_1 \wedge F_2 \in \underset{\bullet}{E}_+(T)$;

(2) if $F_1, F_2 \in \underset{\bullet}{E}_-(T)$, then $F_1 \vee F_2, F_1 \wedge F_2 \in \underset{\bullet}{E}_-(T)$;

(3) if $F_1 \in \underset{\bullet}{E}_+(T), F_2 \in \underset{\bullet}{E}_-(T)$, then $F_1 \vee F_2 \in E_+(T), F_1 \wedge F_2 \in E_-(T)$.

In Natures 2.6 and 2.7, the "OR"/"AND" operation of F_1 and F_2 may be either antecedent or consequent.

Chapter 3 Methodology Basis of Extension Engineering

– Extension Innovation Methods

The bridge to apply theory in various practical fields is methods. In order to let more scholars easily use the basic theories of Extenics, this chapter summarizes the studies for many years, and introduces the extension engineering methodology basis – extension innovation methods embarking from the fundamental principles of Extenics.

3.1 Extensible Analysis Methods

In 2.2, we introduced the extensible analysis principle, by which, we obtained a set of formalized methods for extensible analysis of basic-elements.

The extensible analysis methods are the methods to obtain various possible approaches to solve contradictory problems by extension of matter, affair, relation, etc. on the basis of extensible analysis principle of basic-elements. Extensible analysis methods include divergence analysis method, correlation analysis methods, implication analysis methods, and opening-up analysis methods, and they are also referred to as the divergence tree method, correlation network method, implication system (tree) method, and decomposition/combination chain method, given the forms of the results extended by these methods.

When applying the extensible analysis methods, particular attention should be paid to the following: by simply applying the extensible analysis methods we can only obtain the route for extension or the approach to solve contradictory problems, to solve the contradictory problems we must use extension transformations (introduced in 3.2). The examples in this section only introduce the extension route, but do not involve the whole process of solving contradictory problems.

3.1.1 Divergence Tree Method

According to the divergence analysis principle given in 2.2, as to certain contradictory problem, multiple basic-elements can be extended embarking from the goal or condition that is represented by basic-elements, to provide multiple possible approaches to solve the contradictory problems.

In the process of solving practical problems, the better route to the solution can be found by using only one certain divergence analysis principle, and sometimes by comprehensive application of certain principles. This diverging process forms a kind of tree structure, so it’s called a divergence tree.

The general model of a basic-element divergence tree is as follows:

$$
\begin{array}{lcl}
\{(O_i,\ c,\ v_i),\ i=1,\ 2,\ \cdots,\ n\} & (O,\ c,\ v) & \{(O,\ c_i,\ v_i),\ i=1,\ 2,\ \cdots,\ n\} \\
\{(O_i,\ c_i,\ v),\ i=1,\ 2,\ \cdots,\ n\} & & \{(O,\ c_i,\ v),\ i=1,\ 2,\ \cdots,\ n\} \\
\{(O_i,\ c,\ v),\ i=1,\ 2,\ \cdots,\ n\} & & \{(O,\ c,\ v_i),\ i=1,\ 2,\ \cdots,\ n\}
\end{array}
$$

The method to find the route to solve contradictory problems by using the divergence analysis principle is referred to as the divergence tree method, with the following basic steps:

(1) List the goal (condition) basic-element B to be analyzed;

(2) Select and apply the divergence analysis principle according to the condition for solving the contradictory problem;

(3) Extend multiple basic-elements $B_1, B_2, \cdots, B_n$ from B;

(4) Judge if the route to solve the contradictory problem is found, if yes, it ends, otherwise enter the next step;

(5) Further extend B_i until the route to solve the contradictory problem is found.

[**Example 3. 1**] In the hall corridor of a certain hotel, there are two hollow columns that are only decorative but do not bear load, occupying floor area but non-profitable. The route to solve this problem is studied by using the divergence tree method as follows.

Suppose $M = (\text{cylinder, location, hall corridor}) \underline{\underline{\Delta}} (O_m, \text{ location, hall corridor})$, according to divergence analysis principle, we obtain:

$$M \text{—}| \begin{cases} M_1 = (O_m, \text{ function, decoration} \wedge \text{not load bearing}) \text{—}| M_{11} = (O_m, \text{ function, exhibit}) \text{—}| M_{111} = (\text{prism, function, exhibit}) \\ M_2 = (O_m, \text{ internal structure, hollow}) \\ M_3 = (O_m, \text{ use value, } 0) \text{—}| M_{31} = (O_m, \text{ ust right, hotel owner}) \text{—}| M_{311} = (\text{prism, use right, hotel owner}) \\ M_4 = (O_m, \text{ shape, cylinder}) \text{—}| M_{41} = (O'_m, \text{ shape, prism}) \text{—}| \begin{cases} M_{411} = (\text{prism, shape, prism}) \\ M_{412} = (\text{showcase, shape, prism}) \end{cases} \end{cases}$$

divergence tree obtained according to the above analysis:

$$M -| \begin{cases} M_1 -| M_{11} -| M_{111} \\ M_2 \\ M_3 -| M_{31} -| M_{311} \\ M_4 -| M_{41} -| \begin{cases} M_{411} \\ M_{412} \end{cases} \end{cases}$$

i.e. the cylinder columns can be reconstructed into prisms showcased to exhibit objects. The hotel owners, for they have the right of usage, can exhibit the objects that can bring profits for the hotel. From

$$M_{311} -| \begin{cases} M_{3111} = (\text{prism, ust right, borrower}) \\ M_{3112} = (\text{prism, use value, } a) \end{cases}$$

$$M_{111} -| \begin{cases} M_{1111} = (\text{prism, function, jewelry exhibit}) \\ M_{1112} = (\text{prism, function, perfume exhibit}) \end{cases}$$

the following creative idea can be obtained: the cylinder columns can be reconstructed into prisms showcases and rent them to the dealers of jewelry or perfume, to increase their use value from 0 to a.

In the USA, there is one famous hotel that “operates” the two cylinder columns in the hall corridor by using this idea, and achieves an annual income of 14 million USD by renting them out.

This method is also commonly used in marketing where the requirement met by the product must be recognized. For example, why do people buy watches? It's obviously for knowing time, but is this the only requirement to be met? If yes, one may buy a watch by spending only a few dollars but not thousands or even tens of thousands of dollars. It can be seen that a watch can meet other requirements, such as status, fashion, and a watch can also be used as a gift, while status, fashion and a gift can be represented by other objects, such as a car and a garment, etc. The divergence tree method is exactly the effective method that analyzes these problems.

[**Example 3. 2**] By applying the divergence tree method, analyze the requirement for "shoes" and "wearing shoes" by people, to generate the idea to exploit the market of shoes.

Actually, any pair of shoes can be represented in the form of multi-dimensional matter-elements:

$$M = \begin{bmatrix} \text{shoes } O_m, & \text{material } c_1, & v_1 \\ & \text{size } c_2, & v_2 \\ & \text{color } c_3, & v_3 \\ & \text{style } c_4, & v_4 \\ & \text{brand } c_5, & v_5 \\ & \text{price } c_6 & v_6 \\ & \cdots & \cdots \end{bmatrix}$$

According to the divergence tree method, the measures of shoes O_m about every characteristic are extensible, and consumers can buy the shoes with various measures according to their individual requirements. For example

$$M_1 = \begin{bmatrix} \text{shoes } O_1, & \text{material } c_1, & \text{cowskin} \\ & \text{size } c_2, & 40 \\ & \text{color } c_3, & \text{black} \\ & \text{style } c_4, & \text{boss} \\ & \text{brand } c_5, & \text{Fuguiniao} \\ & \text{price } c_6 & ￥200 \\ & \cdots & \cdots \end{bmatrix}, \quad M_2 = \begin{bmatrix} \text{shoes } O_2, & \text{material } c_1, & \text{sheepskin} \\ & \text{size } c_2, & 36 \\ & \text{color } c_3, & \text{white} \\ & \text{style } c_4, & \text{leisure} \\ & \text{brand } c_5, & \text{Fuguiniao} \\ & \text{price } c_6 & ￥150 \\ & \cdots & \cdots \end{bmatrix}, \cdots$$

The enterprise can develop various products according to different requirements of different types of consumers.

In terms of the shoes seller, the key is not the divergence analysis of the shoes, but divergence analysis of the consumer requirement, i.e. extensible analysis of the consumer requirement – "wearing shoes".

The consumer basic requirement for "wearing shoes" can be represented by affair-elements:

$$A = \begin{bmatrix} \text{protect, dominating object } c_{a1}, & \text{feet} \\ \text{acting object } c_{a2}, & \text{person} \\ \text{location } c_{a3}, & \text{on road} \\ \text{time } c_{a4}, & \text{by day} \end{bmatrix}$$

It’s obvious that there are numerous shoes that can meet this basic requirement, but the consumer requirements for shoes are not only this basic one, and various consumers have different requirements.

The following affair-element divergence tree can be obtained according to the divergence tree method:

$$A \dashv \begin{cases} A_1 = \begin{bmatrix} \text{protect}, & c_{a1}, & \text{feet} \\ & c_{a2}, & \text{middle school student} \\ & c_{a3}, & \text{playground} \\ & c_{a4}, & \text{by day} \end{bmatrix} \dashv \begin{cases} A_{11} = \begin{bmatrix} \text{protect}, & c_{a1}, & \text{feet} \\ & c_{a2}, & \text{schoolgirl} \\ & c_{a3}, & \text{on road} \\ & c_{a4}, & \text{by day} \end{bmatrix} \\ A_{12} = \begin{bmatrix} \text{protect}, & c_{a1}, & \text{feet} \\ & c_{a2}, & \text{schoolboy} \\ & c_{a3}, & \text{playground} \\ & c_{a4}, & \text{by day} \end{bmatrix} \end{cases} \\ A_2 = \begin{bmatrix} \text{show}, & c_{a1}, & \text{status} \\ & c_{a2}, & \text{white collar} \\ & c_{a3}, & \text{office} \\ & c_{a4}, & \text{by day} \end{bmatrix} \dashv A_{21} = \begin{bmatrix} \text{show}, & c_{a1}, & \text{status} \\ & c_{a2}, & \text{schoolgirl} \\ & c_{a3}, & \text{school} \\ & c_{a4}, & \text{by day} \end{bmatrix} \dashv A_{211} = \begin{bmatrix} \text{show}, & c_{a1}, & \text{temperament} \\ & c_{a2}, & \text{schoolgirl} \\ & c_{a3}, & \text{school} \\ & c_{a4}, & \text{by day} \end{bmatrix} \\ A_3 = \begin{bmatrix} \text{prevent}, & c_{a1}, & \text{coldness} \\ & c_{a2}, & \text{the aged} \\ & c_{a3}, & \text{on road} \\ & c_{a4}, & \text{in winter} \end{bmatrix} \dashv A_{31} = \begin{bmatrix} \text{prevent}, & c_{a1}, & \text{coldness} \\ & c_{a2}, & \text{schoolgirl} \\ & c_{a3}, & \text{on road} \\ & c_{a4}, & \text{in winter} \end{bmatrix} \\ A_4 = \begin{bmatrix} \text{increase}, & c_{a1}, & \text{height} \\ & c_{a2}, & \text{schoolgirl} \\ & c_{a3}, & \text{school} \\ & c_{a4}, & \text{by day} \end{bmatrix} \\ A_5 = \begin{bmatrix} \text{give}, & c_{a1}, & \text{performance} \\ & c_{a2}, & \text{performer} \\ & c_{a3}, & \text{stage} \\ & c_{a4}, & \text{performing} \end{bmatrix} \end{cases}$$

i.e.

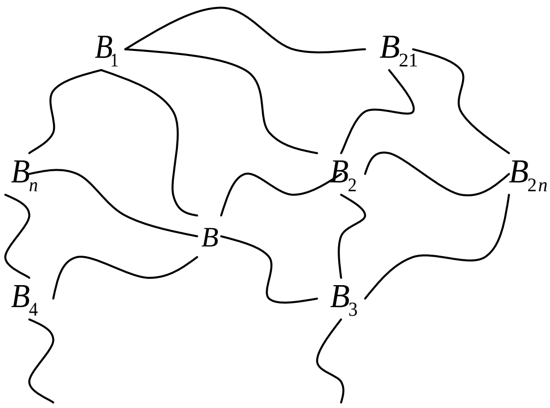
$$A \dashv \begin{cases} A_1 \dashv \begin{cases} A_{11} \\ A_{12} \end{cases} \\ A_2 \dashv A_{21} \dashv A_{211} \\ A_3 \dashv A_{31} \\ A_4 \\ A_5 \end{cases}$$

After researching and evaluating every requirement according to this divergence tree of requirements as well as the data on market surveys, it was found that the shoes that are pertinent to the market of schoolgirls, showing the temperament of schoolgirls, comfortable for wearing and easy for sport are very promising, so this analysis result was utilized by some people who won sudden success because they found the blind spot on the market and avoided the intense market competition. This is also the method of “exploiting the blue sea”.

3.1.2 Correlation Network Method

Any affair or matter in the objective world has a network of relations with other affairs and matters, and because of the existence of these relations, transformation of certain object will cause the change of the object that is related to it.

According to the correlation analysis principle given in 2.2, after the goal and condition of certain contradictory problem are represented by basic-element, this correlation can be described by a formalized method. Because the relation between one basic-element and another basic-element is like a network structure, it's referred to as a correlation network. A correlation tree is a particular case of a correlation network. It's expressed by symbols as follows:



In a correlation network, the change of one basic-element will cause the change of other basic-elements that are related to it in the network. Generally speaking, all correlation networks are dynamic, but at a given moment, the correlation network of a given basic-element is definite and unique.

The method to find the route to solve contradictory problems by a correlation network is referred to as a correlation network method, with the following steps:

(1) Write the basic-element B to be analyzed;

(2) List the correlation network of the basic-element B by using the correlation analysis principle;

(3) Analyze the correlation network to determine the basic-element B_i that causes the change of basic-element B, or the basic-element B_i that is changed because of the change of basic-element B;

(4) Select and apply the basic-element B_i in the correlation network to solve the contradictory problem.

[**Example 3. 3**] In this case a chefs company O_m is going bankrupt because of a failed operation. The reason for its failure is explored by using the correlation network method as follows.

According to the correlation network method, certain characteristics of the same object are correlative. In terms of the chefs company, what should be considered is its operating performance, so correlation analysis of its operating performance is conducted first. Suppose

$$M_1=(O_m, \text{operating performance } c_1, v_1)$$

According to the knowledge of marketing and enterprise management, through correlation analysis of the chefs company, the following matter-elements are correlated with M_1::

$$M_2=(O_m, \text{company image } c_2, v_2)$$

$$M_3=(O_m, \text{product quality } c_3, v_3)$$

$$M_4=(O_m, \text{product variety } c_4, v_4)$$

$$M_5=(O_m, \text{branches layout} c_5, v_5)$$

$$M_6=(O_m, \text{number of branches } c_6, v_6)$$

$$M_7=(O_m, \text{capacity of product development } c_7, v_7)$$

$$M_8=(O_m, \text{staff qualification } c_8, v_8)$$

i.e. the following correlation network is constituted

$$M_1 \sim \left\{\begin{array}{l} M_2 \\ M_3 \\ M_4 \\ M_5 \\ M_6 \end{array}\right. \sim M_7 \sim M_8$$

It can be said that during the operating process of the chefs company, there are problems with various degrees exited on all respects, but these problems are ignored and not well resolved, which leads to the final failure of the company. It can be seen from this correlation network that the company can reverse the passive tide only through large-scale reconstructions, such as changing the company image, improving product quality, increasing product varieties, reasonably arranging a branches layout, increasing the number of branches, improving the capacity of product development, and improving staff quality, etc.

[Example 3.4] The influence of immigrated population in a certain city O_1 on other respects of the city is analyzed by a correlation network method:

Suppose $M_1=(\text{city } O_1, \text{ amount of immigrated population } c_1, v_1)=(O_1, c_1, v_1)$, it can be known from professional knowledge and the knowledge of statistics that M_1 has the following correlations:

$$M_1\sim\begin{cases} M_2=(O_1, \text{ total population } c_2, v_2) \\ M_3=(O_1, \text{ employment opportunities } c_3, v_3) \\ M_4=(O_1, \text{ economic growth rate } c_4, v_4) \\ M_5=(O_1, \text{ quantity of employment } c_5, v_5) \end{cases}$$

and

$$M_3\sim M_5\sim\left.\begin{cases} M_{51}=(\text{construction industry } O_{31}, c_5, v_{51})\sim M_{511}=(\text{construction industry } O_{31}, \text{ civil construction engineering amout } c_{51}, v_{511}) \\ M_{52}=(\text{service industry } O_{32}, c_5, v_{52})\sim M_{521}=(\text{service industry } O_{32}, \text{ quantity of service items } c_{52}, v_{521}) \\ M_{53}=(\text{commerce } O_{33}, c_5, v_{53})\sim M_{531}=(\text{commerce } O_{33}, \text{ livensss } c_{53}, v_{531}) \end{cases}\right\}\sim M_4$$

$$M_2\sim\begin{cases} M_{21}=(O_1, \text{ housing demand } c_{21}, v_{21})\sim M_{511} \\ M_{22}=(O_1, \text{ education demand } c_{22}, v_{22})\sim M_{221}=(O_1, \text{ demand for teachers } c_{221}, v_{221}) \\ M_{23}=(O_1, \text{ traffic demand } c_{23}, v_{23})\sim M_{231}=(O_1, \text{ degree of road crowdedness } c_{231}, v_{231}) \\ M_{24}=(O_1, \text{ food demand } c_{24}, v_{24})\sim M_{521} \end{cases}$$

The following correlation network can be obtained from the above analysis:

$$M_1 \sim \begin{cases} M_2 \sim \begin{cases} M_{21} \sim M_{511} \\ M_{22} \sim M_{221} \\ M_{23} \sim M_{231} \\ M_{24} \sim M_{521} \end{cases} \\ M_3 \sim M_5 \sim \left. \begin{cases} M_{51} \sim M_{511} \\ M_{52} \sim M_{521} \\ M_{53} \sim M_{531} \end{cases} \right\} \sim M_4 \end{cases}$$

The administrators of the city must consider the various correlation networks while solving the contradictory problems, otherwise new contradictory problems may occur while one contradictory problem is solved.

3.1.3 Implication System Method

Implication system method is the method to find the route to solve contradictory problems by analyzing the goal or condition of the contradictory problem by the implication analysis principle given in 2.2, with the basic steps as follows:

(1) List the basic-element, transformation or problem to be analyzed;

(2) Establish implication system according to known information and the implication analysis principle;

(3) According to the new information generated during the process of solving the problem, increase or interrupt the implication system on certain layers of the system; in case of no new information, enter the next step;

(4) Realize the antecedent basic-element, transformation or problem by realizing the last consequent basic-element, transformation or problem, to find the route to solve the contradictory problem.

Implication systems, no matter what kind, can be divided into "AND implication system" and "OR implication system", which should be distinguished during specific application.

[**Example 3. 5**] A certain toothpaste company O_m made all efforts in production and sales of toothpaste products to improve its profit, so as to increase its sales volume. For consumers, toothpaste is a daily supply, but the total sales volume of toothpaste is almost fixed, because it's impossible for consumers to brush their teeth seven or eight times a day. The route to solve this problem is analyzed by using an implication system method as follows.

According to the implication system method:

M=(company O_m, annual profit, v_{m1})

⇑

M_1=(company O_m, sales volume, v_{m21})　　　M_2=(company O_m, quantity of customers, v_{m22})

⇑　　　　　　　　　　　　⇑

$$A_1 = \begin{bmatrix} \text{buy}, & \text{dominating object}, & \text{toothpaste} \\ & \text{quantity}, & v_{a1}\text{tube / person•month} \end{bmatrix} \qquad M_{21} = \begin{bmatrix} \text{toothpaste}, & \text{type}, & v_{m211} \\ & \text{package form}, & \text{various} \end{bmatrix}$$

$$\Uparrow$$

$$A_2=\begin{bmatrix}\text{use}, & \text{dominating object}, & \text{toothpaste}\\ & \text{quantity}, & v_{a2}\text{tube / person•month}\end{bmatrix}$$

$$\Uparrow$$

$$A_3=\begin{bmatrix}\text{use}, & \text{dominating object}, & \text{toothpaste}\\ & \text{quantity}, & v_{a3}\text{gram / person•time}\end{bmatrix}$$

Therefore, according to the characteristics of the implication system, in order to change M, A_3 or M_{21} should be transformed. But it's known from the operating experience for many years that it's hardly effective to increase the quantity of customers by further changing M_{21}, so the enterprise sales volume can only be increased by changing A_3, i.e. increasing the consumption amount by the consumer each time. The specific practice is as follows: slightly enlarge the opening of the toothpaste tube, and then the consumption amount each time will be increased. The detailed transformation method will be introduced in the next section.

[**Example 3.6**] A cold drink is scarcely popular in winter, but a certain cold drinks shop has a large stock of ice creams that cannot be sold, thus the cold drinks shop will lose money. The possible idea for the shop to sell the cold drinks is analyzed by the implication analysis method of affair-elements as follows.

The goal affair-element of the problem is

$$A_g=\begin{bmatrix}\text{buy}, & \text{dominating object}, & \text{cold drinks}\\ & \text{acting object}, & \text{customers}\end{bmatrix}=\begin{bmatrix}O_{a1}, & c_1, & v_{11}\\ & c_2, & v_{21}\end{bmatrix}$$

Condition affair-element is

$$A_l=\begin{bmatrix}\text{sell}, & \text{dominating object}, & \text{cold drinks}\\ & \text{acting object}, & \text{shop owner}\\ & \text{time}, & \text{winter}\end{bmatrix}=\begin{bmatrix}O_{a2}, & c_1, & v_{12}\\ & c_2, & v_{22}\\ & c_3, & v_{32}\end{bmatrix}$$

Implication analysis of goal affair-element:

$$A_g$$

$$\Uparrow$$

or

$$A_1=\begin{bmatrix}\text{thirsty}, & c_2, & \text{customers}\\ & \text{location}, & \text{closed place}\end{bmatrix},\qquad A_2=\begin{bmatrix}\text{reduce temperature}, & c_2, & \text{customers}\\ & \text{location}, & \text{closed place}\end{bmatrix}$$

$$\Uparrow$$

$$A_{11}=\begin{bmatrix}\text{eat}, & c_2, & \text{customers}\\ & c_1, & \text{dry foods}\\ & \text{location}, & \text{closed place}\end{bmatrix}$$

$$\Uparrow$$

or

$$A_{111}=\begin{bmatrix}\text{present}, & c_2, & \text{shop owner}\\ & c_1, & \text{dry foods}\\ & \text{location}, & \text{closed place}\end{bmatrix},\quad A_{112}=\begin{bmatrix}\text{buy}, & c_2, & \text{customers}\\ & c_1, & \text{dry foods}\\ & \text{location}, & \text{closed place}\end{bmatrix}$$

$$\Uparrow$$

$$A_{1121}=\begin{bmatrix} \text{sell}, & c_2, & \text{shop owner} \\ & c_1, & \text{dry foods} \\ & \text{location}, & \text{closed place} \end{bmatrix}$$

Wherein, $l_1=\left(\overline{\text{supply}},\quad h_1,\quad \text{water}\right)$, i.e. the affair-element implication system is

$$
\begin{array}{ccccc}
 & & A_g & & \\
 & & \Uparrow & & \\
 & & \text{or} & & \\
 & A_1 & & A_2 & \\
 & \Uparrow & & & \\
 & A_{11} & & & \\
 & \Uparrow & & & \\
 & \text{or} & & & \\
A_{111} & & A_{112} & & \\
 & & \Uparrow & & \\
 & & A_{1121} & &
\end{array}
$$

The implication channels are:

$D_1:\ A_{111}\Rightarrow A_{11}\Rightarrow A_1\Rightarrow A_g$
$D_2:\ A_{1121}\Rightarrow A_{112}\Rightarrow A_{11}\Rightarrow A_1\Rightarrow A_g$
$D_3:\ A_2\Rightarrow A_g$

Generally in condition l_l, $A_2\overline{@}$, so the channels can be selected are D_1 and D_2, i.e. $A_{111}@$ or $A_{1121}@$, both of which can realize $A_g@$, so A_{111} or A_{1121} can be used as two ideas to solve this contradictory problem.

According to the above implication analysis, it's considered that the customers will buy cold drinks if they eat dry foods in closed public places (without water supply), while the stuff to be eaten by customers must be delicious and cheap. But even the most delicious and cheapest stuff may not be bought by the customers; in this case, they won't buy the cold drinks. Therefore, the mode of "present", i.e. the idea A_{111} must be selected.

The idea A_{111} is concreted by using the divergence tree method as follows:

$$A_{111} - | A_{1110} = \begin{bmatrix} \text{present}, & c_1, & \text{dry food} \\ & c_2, & \text{shop owner} \\ & c_4, & \text{closed place} \\ & \text{quantity}, & \text{a small pack} \end{bmatrix} - | \begin{cases} A'_{1110} = \begin{bmatrix} \text{present}, & c_1, & \text{fried peas} \\ & c_2, & \text{shop owner} \\ & c_4, & \text{theater} \\ & c_5, & \text{a small pack} \end{bmatrix} \\ A''_{1110} = \begin{bmatrix} \text{present}, & c_1, & \text{fried peanuts} \\ & c_2, & \text{shop owner} \\ & c_4, & \text{circus} \\ & c_5, & \text{a small pack} \end{bmatrix} \\ A'''_{1110} = \begin{bmatrix} \text{present}, & c_1, & \text{popcorn} \\ & c_2, & \text{shop owner} \\ & c_4, & \text{cinema} \\ & c_5, & \text{a small pack} \end{bmatrix} \\ \qquad \cdots\cdots \end{cases}$$

And then according to the geographical location of the cold drinks shop and the diet habit of the population, as well as the price of food, the following is finally selected

$$A^{*}_{1110} = \begin{bmatrix} \text{present}, & c_1, & \text{fried peas} \\ & c_2, & \text{shop owner} \\ & c_4, & \text{theater} \wedge \text{circus} \\ & c_5, & \text{a small pack} \end{bmatrix}$$

As a concreted idea: the owner of the cold drinks shop can buy some raw peas, fry them at home, pack them in small quantities, go to the door of the circus and the theater, and present the hot fried peas to the audiences as gifts. During performance interval, the owner of the cold drinks shop can organize some children to run into the circus and theater to sell ice creams, etc. The audience members who have dry lips and dry throats after eating the hot peas will immediately buy the ice creams one after another. Now, the contradictory problem is successfully solved.

3.1.4 Decomposition/Combination Chain Method

Decomposition/combination chain method is the method to find the approach to solve contradictory problems by combination and decomposition of basic-elements according to the extensible analysis principle of basic-elements. Both combination and decomposition are effective methods to solve contradictory problems.

Steps of decomposition/combination chain method:

(1) Represent the goal and condition of certain contradictory problems with basic-element B;

(2) Using divergence tree method, find the combinable basic-element B_i of B, or decompose B into several basic-elements $\{B_i, i=1,2,\ldots,n\}$;

(3) Investigate whether the combined or decomposed basic-elements can be used to solve the contradictory problem, if not, enter the next step;

(4) Conduct divergence analysis, implication analysis or correlation analysis of B, to obtain a group of basic-elements $\{B_j, j=1,2,\ldots,m\}$, in case this group of basic-elements still cannot solve the contradictory

problem, consider finding their combinable basic-element or consider whether they can be decomposed;

(5) Investigate whether the combined or decomposed basic-elements can be used to solve the contradictory problem.

[Example 3.7] It's very difficult to measure the thickness of a piece of thin paper by an ordinary ruler. The goal basic-element of this problem is:

$$G=(\text{paper } O_{m1},\ \text{thickness},\ x\text{mm}),\ x<<1\text{mm},$$

The condition basic-element is:

$$L=(\text{ruler } O_m,\ \text{measuring range}, <1\text{mm},100\text{mm}>),\ \text{and } x<<1\text{mm}.$$

It's obvious that the condition of this problem cannot be changed, and we can only embark from analyzing the goal. According to the combinability of paper (it's obvious that it cannot be further decomposed), the combinable basic-element of G can be found

$$G_i=(\text{paper } O_{mi},\ \text{thickness},\ x\text{mm}), i=2,3,\cdots,100$$

Then the goal of the original problem is changed to

$$G'=\sum_{i=1}^{100}(O_{mi},\ \text{thickness},\ x\text{mm})=(\sum_{i=1}^{100}O_{mi},\ \text{thickness},\ 100x\text{mm})$$

It's obvious $100x\in<1,100>$, i.e. the thickness of 100 pieces of paper can be measured by the ruler, suppose $a$mm, then the original problem is soluble, i.e. $100x=a,\ x={}^{a}\!/_{100}$ mm.

[Example 3.8] There is a ceiling lamp installed on the ceiling in an office, 3.2m above the floor and the failed bulb should be replaced, but there is no ladder. A certain person is 1.75m high, with touch height of 2.25m. This problem is an incompatible problem, with the goal of

$$G=\begin{bmatrix}\text{repair}, & \text{dominating object}, & \begin{bmatrix}\text{ceiling lamp D}, & \text{location}, & \text{ceiling}\\ & \text{height above floor}, & 3.2\text{m}\end{bmatrix}\\ & \text{acting object}, & \text{person A}\end{bmatrix}$$

and the condition of L=(person A, body height, 1.75m).

We take the evaluation characteristic c_0="height", c_{0s} is the G-required height to be realized, because the room height is 3.2m, then the value domain of certain object about c_{0s} is X_0=<3.2, 3.7> (i.e. the lamp can be repaired even if the height is 0.5m higher than the room height, because the person can stoop), c_{0t} is the height provided by the object in condition L. Here the object is person A, because the lamp is to be repaired manually, the touch height should be considered, i.e. $c_{0t}(L)$=2.25m(touch height), while the actual height of person A is 1.75m. Now

L =(person A, body height, 1.75m), suppose the touch height is 0.5m higher than the body height of this person, then $c_{0t}(L)$=2.25m.

The route to solve this contradictory problem analyzed by extensible analysis method is given as follows:

(1) Using the divergence tree method:

$$L = (\text{person A, height, 1.75m}) \dashv \begin{cases} L_1 = (\text{person } A_1\text{, height , 1.60m}) \\ L_2 = (\text{person } A_2\text{, height , 1.85m}) \\ L_3 = (\text{person } A_3\text{, height , 1.95m}) \\ L_4 = (\text{table } A_4\text{, height , 1.10m}) \\ L_5 = (\text{chair } A_5\text{, height , 0.60m}) \\ L_6 = (\text{cabinet } A_6\text{, width, 1.00m}) \end{cases}$$

While for the highest person A_3, there is $c_{0t}(L_3)$=1.95+0.5=2.45(m) <3.2(m), so the first three matter-elements diverged this way cannot solve the contradictory problem.

(2) Using combination chain method:

$L \oplus L_1$=(person A, height , 1.75m)$\oplus$(person A_1, height , 1.60m)

$L \oplus L_4$=(person A, height , 1.75m)$\oplus$(table A_4, height , 1.10m)

$L \oplus L_5$=(person A, height , 1.75m)$\oplus$(chair A_5, height , 0.60m)

$L \oplus L_6$=(person A, height , 1.75m)$\oplus$(cabinet A_6, width, 1.30m)

We have

$c_{0t}(L \oplus L_1)$=1.75+0.8+0.5=3.05(m), i.e. person A_1 can ride on the shoulders of person A, now the touch height of person A_1 can only be calculated by about half body height plus 0.5m;

$c_{0t}(L \oplus L_4)$= 1.75+0.5+1.10=3.35(m), i.e. person A can stand on table A_4;

$c_{0t}(L \oplus L_5)$= 1.75+0.5+0.60=2.85(m) , i.e. person A can stand on chair A_5;

$c_{0t}(L \oplus L_6)$= 1.75+0.5+1.30=3.55(m), i.e. person A can stand on the pull-down cabinet A_6;

thus we obtain multiple possible routes to solve the contradictory problem.

3.2 Extension Transformation Methods

While the extensible analysis methods provide only the multiple approaches to solve contradictory problems, extension transformations must be implemented to realize solution to the contradictory problems. This section will introduce some common extension transformation methods.

3.2.1 Basic Transformation Methods

1. Basic transformation methods of basic-elements

After extensible analysis of basic-elements, the basic transformation methods of basic-elements can be selected and applied to solve the contradictory problem.

Before implementing the transformation, we should first judge if the problem's goals and conditions can be transformed, if yes, select specific transformation methods according to the actual problem.

Table 3.1 Basic Transformations of Goals and Conditions

Element / Selection / Methods	Goals			Conditions		
	Object	Characteristic	Measure	Object	Characteristic	Measure
Substitution						
Increase						
Decrease						
Expansion						
Contraction						
Decomposition						
Duplication						

Because the goals and conditions of the problem can be represented by basic-elements, what is obtained through extensible analysis are also basic-elements, when selecting transformation, we should also consider which of the goal, characteristics and measures of goal basic-elements and condition basic-elements is to be transformed. In addition, because of the conductive function of transformation, the transformation for the object of a basic-element may cause the change of the measure corresponding to certain characteristic; likewise, the transformation of a certain measure may also cause change of its corresponding object. Attention must be paid to this kind of conductive transformation during implementing the transformation.

The steps to solve contradictory problems by using basic transformation methods of basic-elements are as follows:

(1) Select the basic-element B to be transformed;

(2) Find the extensible basic-element set of basic-element B by using the extensible analysis principle;

(3) Select the basic transformation to be implemented:

According to the extension transformation principle introduced in 2.4:

1) In case of substitution transformation, find the basic-element that can substitute B from the divergence basic-elements set of B;

2) In case of increasing transformation, find the basic-element that can combine with B from the combinable basic-elements set of B;

3) In case of decreasing transformation, analyze whether B is a dividable basic-element, because only dividable basic-elements can be decreasingly transformed;

4) In case of expansion transformation, the object or measure of basic-element B must be expandable;

5) In case of contraction transformation, the object or measure of basic-element B must be contractible;

6) In case of decomposition transformation, we should also analyze whether B is a dividable basic-element, if yes, the basic-element B can be decomposed to many basic-elements.

(4) Determine the solution transformation. The result of each transformation may not be necessarily used to solve the contradictory problem, only the transformation that changes the compatibility of the contradictory problem from less than 0 to more than 0 is the solution transformation of the contradictory problem, or referred to as the extension strategy to solve the contradictory problem (for a detailed process of solving contradictory problems see Chapter 4).

(5) Adopt the operating equation of transformation. If all basic transformations are not capable for solving the contradictor problem, we should consider their operating equation or other transformation methods.

[Example 3.9] It's known that the main function of a photo is to be kept as a souvenir (except for a certificate photo), which can be kept by oneself or presented to relatives and friends. A photo is usually kept in an album, hung on the wall, or put on the table, etc. For the photos of ordinary people, the function and placement seems significantly limited, but for the photos of celebrities, especially singing stars and film stars, the "function" and "placing location" is much more. They can be used as an image ambassador of certain enterprises, as advertisements of the enterprise's product; they can appear in newspapers, magazines, pinup calendars, desk calendars, or appear on a curbside advertising column, or can be printed on garments that can be worn by their admirers.

Suppose $M=(\text{photo A},\ \ \text{placing location},\ \ \text{album})$, according to divergence analysis principle:

$$M \dashv \begin{cases} (\text{photo A},\ \ \text{placing location},\ \ \text{desk calendar}) \\ (\text{photo A},\ \ \text{placing location},\ \ \text{cup}) \\ (\text{photo A},\ \ \text{placing location},\ \ \text{pinup calendar}) \\ (\text{photo A},\ \ \text{placing location},\ \ \text{T-shirt}) \\ \cdots \end{cases}$$

If we make the following substitution transformation:

$$T_1 M = (\text{photo A},\quad \text{placing location},\quad \text{desk calendar}) = M'$$

We obtain the following creative idea: to make a personal desk calendar, i.e. print the personal photo onto a desk calendar that can be put on the desk of oneself or presented as a gift to relatives and friends.

If we further make: $T_2 M = (\text{photo A},\quad \text{placing location},\quad \text{T-shirt}) = M''$

$$T_3 M'' = \{M'', M''_*, M''_*, \cdots, M''_*\}$$

We obtain the creative idea: to make a personal T-shirt, i.e. print the personal photo on a T-shirt, which, after multiple duplication transformations, can be worn by oneself or presented to relatives and friends.

Similarly, we can make cups with personal photos, i.e. burn the personal photo on a batch of cups. Because this kind of creative idea is particularly meaningful, for example, people that live far away from their parents can send the pinup calendar or desk calendar printed with their personal elegant demeanor on festivals, their parents must be very delighted. Therefore, it allows people disregard the making cost, the price of a desk calendar can be hundred yuan, and a T-shirt can be bought for 10 yuan will be sold for 50 yuan after printed with a photo.

In order to increase profits and attract customers, certain photo studios adopted many marketing measures, such as preferential film development, presents of large photos and photo frames, etc. for a certain amount of consumption, to win long-term benefits. Actually, according to the extensible analysis and extension transformation of the photo's function and placing location, multiple creative ideas of sales can be obtained. The above example is precisely a good creative idea.

[Example 3.10] In order to open the rural market of certain regions, in other words, to let the farmers in certain regions become customers, an enterprise of household electrical appliances made the following extensible analysis of products through analyzing the rural customer requirements.

$$M_1 = \begin{bmatrix} \text{product A}, & \text{types of function}, & 6 \\ & \text{price}, & 3000\ \text{Yuan} \end{bmatrix} \dashv \begin{cases} M_{11} = \begin{bmatrix} \text{product A}, & \text{types of function}, & 5 \\ & \text{price}, & 2600\ \text{Yuan} \end{bmatrix} \\ M_{12} = \begin{bmatrix} \text{product A}, & \text{types of function}, & 4 \\ & \text{price}, & 2000\ \text{Yuan} \end{bmatrix} \\ M_{13} = \begin{bmatrix} \text{product A}, & \text{types of function}, & 3 \\ & \text{price}, & 1700\ \text{Yuan} \end{bmatrix} \end{cases}$$

The following transformations are implemented: product functions are decreased, and product price is reduced, i.e. decreasing transformation of product functions and corresponding decreasing transformation of product prices are implemented, i.e.

$$T_1 M_1 = M_{13}$$

In addition, home-delivery service is provided, so as to open the rural market.

2. Basic transformation methods of dependent criterion

The basic transformation methods of dependent criterion include substitution transformation methods, i.e. the method to substitute the original criterion by a new one; increasing transformation methods, i.e. the method to increase new criterion on the basis of the original one; decreasing transformation methods, i.e. the method to delete part of the original criterion or decrease the requirement; numerical expansion transformation method, i.e.

the method to expand the original criterion by quantitative multiples; numeric contraction transformation method, i.e. the method to contract the original criterion by quantitative multiples; decomposition transformation method, i.e. the method to divide the original criterion to more detailed ones, to allow different criteria to be applicable for different objects.

In the extension set theory, the dependent function established by dependent criterion represents the corresponding relation between the element in the universe of discourse and the real number in the real number field, i.e. represents the degree that an object has certain nature by real number. To solve the contradiction of a problem, the transformation of criterion can be realized by transforming the dependent function.

To study the transformation of criterion is to transform the mapping relation between element and a real number, and the modification or substitution of dependent function can blaze new approaches to solve contradictory problems.

For the transformation method of dependent function, see the corresponding content in 2.7 of this book, which is not explained in detail herein.

[Example 3.11] There is a batch of food-processing raw material u that is nonconforming because some indicators are over standard for some reasons measured by the food production and processing standard $y=k(u)$, i.e. $k(u)\leq 0$. However, if measured by the production and processing standard for animal feed $y'=k'(u)$, it becomes conforming, i.e. $k'(u)\geq 0$. Therefore, this batch of raw material can be sold to feed manufacturers to avoid more loss. This transformation is substitution transformation of criteria i.e. we make

$$T_k k = k'$$

to let the raw material u change from nonconforming to conforming under the new criterion.

3. Basic transformation methods of universe of discourse

The basic transformation methods of universe of discourse include the substitution transformation method, increasing transformation method, decreasing transformation method, and decomposition transformation method. When the universe of discourse is a real number field, we can also conduct numerical expansion transformation and numerical contraction transformation of the universe of discourse. In both classical set and fuzzy set, the universe of discourse is considered definite and unchangeable, while in extension set, the universe of discourse is considered transformable, which provides new ideas to solve contradictory problems.

For example, in the tide of global economic integration, large multinational companies usually transfer their production base from a developed country to a developing country where there are low labor costs and cheap resources, or realize the strategic transformation the situation of “being the location of both production and sales” to “selling local products”, which are the substitution transformations of universe of discourse. While expanding the scope of the applying object of certain product, i.e. expanding the original single object A to A, B, C and D is expansion transformation of universe of discourse. For example, the original applying object of a certain product was infants, and now it is expanded to children and women, etc. which is an expansion transformation of the universe of discourse. Expanding the sales scope of certain products from the original region A to the local province, the whole country and even abroad, is also an expansion transformation of the universe of discourse. In management of sales channels, decidedly weeding the middleman who does not abide by the game rule in the sales channel is a contraction transformation of the universe of discourse.

The greatest revelation given by the transformation of the universe of discourse is that, during the process of solving contradictory problem or innovating idea, we must not “consider something as it stands”, but should dare to conduct substitutions, expansions or contraction transformations of the object to be investigated, to break through the original contradiction of the problem, or to achieve an extremely creative result.

[Example 3.12] A wine plant in certain regions of the national minority produces a kind of rice wine, Bamboo Tube Wine, which is very popular in the local population because of its high quality and low price. However, because it is limited by the local economic environment, the local sales volume of this wine has never been expanded. With the local tourism development, the amount of tourists visiting the region has been growing year by year. Pertinent to this group of consumers, the wine plant produces a kind of Bamboo Tube Wine A with high quality and a high price, and combines it with the bamboo handcraft that is an intense feature of the national minority, but the sales situation is still ordinary. It's discovered through the survey that the wine tube is too heavy to carry; so many tourists can buy only one or two tubes even if they want more, and the majority of them merely feel powerless and frustrated when facing the tubes. Next, we'll form the idea to expand the market by using the thinking of transformation of the universe of discourse.

(1) Determine the original object field of the problem to be studied

Universe of discourse of the problem to be studied U = {local customers and tourists visiting the region}. It can be seen from the above situation of the wine plant that their sales activities attract customers only by the simple and natural charm of the product itself, and their general thinking is to ask customers to wait and buy the wine here.

(2) Select transformation of the universe of discourse

① Make substitution transformation of the universe of discourse: for the new product A fails to win large market in the original universe of discourse, we make

$$T_1U=U_1$$

i.e. we give up the original universe of discourse, and select the commercial city that has diet habit similar to the local region and relatively developed economy as new universe of discourse U_1, on which to expand market. The sales in universe of discourse U_1 is the thinking of "sales by sending the products out".

② Make increasing/decreasing transformation of the universe of discourse:

$$T_2U=U\oplus U'=U_2$$

i.e. the universe of discourse is expanded to the peripheral provinces on the original basis. Because the consumers in U_2 have characteristics similar to that of the consumers in U and are in ordinary economic situations, if we make ordinary advertisements and publicity or sell ordinary Bamboo Tube Wine in U_2, it's predicted that the result will not be desirable.

If we further make decreasing transformation of the universe of discourse in U_2

$$T_3U_2=U_3 \qquad (U_3\subset U_2)$$

i.e. U_3 is a particular group in U_2, such as the local aged people who are fond of a small quantity of rice wine, the plant can produce a special wine pertinent to the customers in U_3 – Longevity Rice Wine, conduct some transformations of the wine package and capacity, and make publicity utilizing the "green" characteristic of the wine, better sales performance will be achieved.

③ Make decomposition transformation of the universe of discourse: producing different wines and implementing different sales modes pertinent to different consuming groups and this kind of transformation can be made in the original universe of discourse, or in the substituted universe of discourse, or in the expanded universe of discourse. If we make

$$T_4U=\{U_1, U_2, U_3\}$$

wherein U_1={all young and middle-aged women in U}, U_2={young and middle-aged men in U}, U_3={all aged people in U}. Better effect will be achieved by adopting different packages, capacities, alcohol degrees and sales modes of different products in the sub-universe of discourse that are more pertinent.

The wine plant can comprehensively evaluate which transformation to be adopted according to the factors of publicity costs, transport costs, estimate of sales volume, and price/cost, etc. after transformation.

3.2.2 Operation Methods of Transformations

When solving contradictory problems, apart from the basic transformation methods introduced above, operation of transformation can also be used to generate the strategy to solve the contradictory problems. The basic operation methods of extension transformation includes four types of product, AND, OR, and inverse operations. In the process of solving contradictory problems, the operation methods of transformation are commonly used, which include product transformation methods, AND transformation methods, OR transformation methods and inverse transformation methods. In addition, other integration methods of transformation are also commonly used, such as medium transformation, complementation transformation, etc. These methods are introduced as follows:

1. Product transformation methods

The product transformation method is commonly used in the situation that the contradictory problem is solved by successively implementing two transformations. For example, one needs to go to Zhuhai from Beijing, who can directly reach Zhuhai by air. But if limited by economic conditions, he must first reach Guangzhou by train and then reach Zhuhai by coach. The second method adopts the product transformation method.

[Example 3.13] The operation on production line in assembly plants is to conduct assembly by conveying component A_1 from location a_1 to location a_2 of component A_2, and then to location a_3 of component A_3, until the complete product is assembled, which utilizes the product transformation method, i.e.

Suppose $M_1=(\text{component } A_1,\ \ \text{location},\ \ a_1)$, …, $M_n=(\text{component } A_n,\ \ \text{location},\ \ a_n)$, we make the following transformation:

$$T_1M_1=M_1\oplus M_2=(\text{component } A_1\oplus\text{component } A_2,\ \ \text{location},\ \ a_2)=M_2'$$

$$T_2M_2'=M_2'\oplus M_3=M_3'$$

……

$$T_{n-1}M_{n-1}'=M_{n-1}'\oplus M_n=M_n'$$

Finally, through transformation $T=T_{n-1}T_{n-2}\cdots T_2T_1$, assemble n components to a final product M_n' on location a_n.

2. AND transformation methods

AND transformation methods are commonly used in the situation that the contradictory problem is solved by simultaneously implementing two transformations.

[Example 3.14] During product innovation, transformation of material is usually accompanied by the transformation of technology. To replace the material of certain products such as wood, by plastic, the manufacturing technology must be transformed simultaneously, and these two transformation that are simultaneously conducted is AND transformation, i.e. we make

$$T_{1A}\,(\text{product } A,\ \text{material},\ \text{wood}) = (\text{product } A,\ \text{material},\ \text{plastic})$$

$$T_{2A}\,(\text{product } A,\ \text{manufacturing technology},\ a) = (\text{product } A,\ \text{manufacturing technology},\ b)$$

Only through transformation $T_A=T_{1A}\wedge T_{2A}$ can the product innovation be realized.

[Example 3.15] In order to activate the market of real estate, the government simultaneously implemented the following three transformations:

$$T_{1P}\,(\text{bank, deposit interest rate},\ p_1) = ((\text{bank, deposit interest rate},\ p_1'), \qquad p_1 > p_1'$$

$$T_{2P}\,((\text{bank, loan interest rate},\ p_2) = ((\text{bank, loan interest rate},\ p_2'), \qquad p_2 > p_2'$$

$$T_{3P}\,(\text{house for employee, method to obtain, welfare house distribution})$$

$$= (\text{house for employee, method to obtain, purchase on market})$$

then $T_P = T_{1P} \wedge T_{2P} \wedge T_{3P}$, and the target to activate the market of real estate can be achieved.

When using AND transformation, particular attention should be paid to the fact that every transformation should be compatible with each other, otherwise the expected target will not be achieved. In T_{2P} of the above example, if $p_2 < p_2'$, i.e. increasing bank loan interest rate, then the expected target can be hardly achieved by $T_{1P} \wedge T_{2P} \wedge T_{3P}$.

3. OR transformation methods

OR transformation methods are the methods to solve contradictory problems by selecting any one or more transformation in many transformations.

[Example 3.16] As to the same product, different consumers tend to purchase in different modes, therefore during sales, usually multiple transformations can be designed to allow anyone of them to exert the function of market expansion, which is the application of OR transformation method. For example, when exploring the market of real estate, if anyone of the following transformations: T_1, T_2, T_3 is adopted, denoted as $T= T_1\vee T_2\vee T_3$, different customers may independently select the transformation method that is suitable for oneself:

$$T_1\,(\text{house } A,\ \text{payment mode, one-off}) = (\text{house } A,\ \text{payment mode, installment})$$

$$T_2\begin{bmatrix}\text{house } A, & \text{price}, & 500000\text{ Yuan}\\ & \text{payment mode}, & \text{one-off}\end{bmatrix}=\begin{bmatrix}A, & \text{price}, & 450000\text{ Yuan}\\ & \text{payment mode}, & \text{one-off}\end{bmatrix}$$

$$T_3\left(\text{house } A,\quad \text{price},\quad 500000\text{ Yuan}\right)=\left(\text{house } A\otimes\text{present } B,\quad \text{price},\quad 500000\text{ Yuan}\right)$$

4. Inverse transformation method

Inverse transformation method is the method that recovers certain transformed objects to the original one.

[Example 3.17] A child *A* who plays in the meadow goes home with a caterpillar on his hand. His mother who is afraid of caterpillars but does not want to tell her son she's afraid, says: "bring the caterpillar out, or its mother will get worried if she does not find it!" The child goes out obediently. After a while, he comes back with two caterpillars in his hand and says to his mother: "I brought its mother, so she wouldn't worry."

Next, we'll analyze the process where the mother and the son solve the contradictory problem in the above example. Suppose

$$M_1 = \text{(son caterpillar, dwelling place, meadow)}$$

$$M_2 = \text{(mother caterpillar, dwelling place, meadow)}$$

It can be found that the mother considers her son made the transformation

$$T_1 M_1 = \text{(son caterpillar, dwelling place, home of child } A\text{)} = M_1'$$

to let $M_1' \uparrow M_2$. In order to solve this contradiction, inverse transformation T_1^{-1} of transformation T_1 must be made, to let

$$T_1^{-1} M_1' = T_1^{-1}\text{(son caterpillar, dwelling place, home of child } A\text{)}$$

$$= \text{(son caterpillar, dwelling place, meadow)} = M_1$$

While the son considers the contradiction between M_1' and M_2 can be solved only by further implementing T_2 to M_2, to let

$$T_2 M_2 = T_2 \text{ (mother caterpillar, dwelling place, meadow)}$$

$$= \text{(mother caterpillar, dwelling place, home of child } A\text{)} = M_2'$$

i.e. $M_1' \downarrow M_2'$. Here, what was made by the child is product transformation $T = T_2\ T_1$, which can also solve the contradictory problem.

5. Medium transformation method

The so-called medium transformation refers to the transformation to realize the goal by certain transformation through introducing a basic-element with the function of medium when the goal cannot be realized by certain transformation. Medium transformation is a particular product transformation.

Generally, given basic-element B_0, but failed to make transformation T to let $TB_0 = B$, we can first make transformation φ to let $\varphi B_0 = B_1$, and then make $T_1 B_1 = B_2$ and $T_2 B_2 = B$ to let

$$B = T_2 B_2 = T_2(T_1 B_1) = T_2 T_1(\varphi B_0) = (T_2 T_1 \varphi) B_0$$

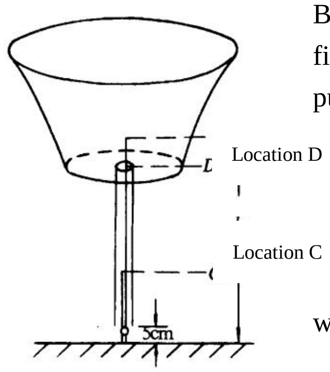
We call transformation φ medium transformation, and basic-element B_1 medium basic-element.

In particular, if $T_1 B_1 = B$, transformation T_2 is not necessary.

For example, the "cableway" installed between the foot and top of the mountain in a scenic spot is a "medium" for people to quickly reach the top of the mountain from its foot without effort; for people to reach the opposite bank of a river. Both "bridge" and "boat" are media to realize this goal. "Intermediary company" and "go-between" also belong to the "media".

[Example 3.18] One who is washing chopsticks in a basin carelessly drops chopstick A into the water pipe under the basin, and the opening of the water pipe is only 5cm under the floor, so the chopstick cannot be taken out from under the floor, but a hand cannot be put into it from above. This problem can be solved by the following method:

Suppose $M_0 = \begin{bmatrix} \text{chopstick A}, & \text{location}, & \text{location C} \\ & \text{diameter}, & a \end{bmatrix}$



Because a finger is too short, a longer object B should be used to replace a finger, such as a long bamboo pole, steel bar, thick iron wire, etc., which can be put into the water pipe, i.e. we take

$$M' = \begin{bmatrix} \text{B}, & \text{length}, & h \\ & \text{diameter}, & d \end{bmatrix}$$

where $h > |C\,D|$, $d < r$ (r is diameter of water pipe) , we make

Figure 3.1 Location Diagram of Chopstick A

$$\varphi M_0 = M_0 \oplus M' = \begin{bmatrix} \text{chopstick A} \oplus \text{B}, & \text{location}, & \text{location C} \\ & \text{length}, & h \\ & \text{diameter}, & d \oplus a \end{bmatrix} = M_1$$

and $d \oplus a < r$, here $d \oplus a$ equal to the arithmetic sum $d + a$ of $d + a$, then we make

$$T_1 M_1 = (\text{chopstick A} \oplus \text{B}, \quad \text{location}, \quad \text{location D}) = M_2$$

$$T_2 M_2 = \{(\text{chopstick A}, \quad \text{location}, \quad \text{location D}), (\text{B}, \quad \text{location}, \quad \text{location D})\}$$

The specific practice of the process is: take a long thin object B with length longer than $|\mathrm{C\,D}|$ and with the sum of its diameter and the diameter of chopstick A less than the diameter of the water pipe, put it into the water pipe, bind chopstick A and B together from under the water pipe, pull it by B to D and then remove B, so chopstick A is at location D. Here, φ is medium transformation, by which A and B are bound together, and are separated after the goal is achieved.

6. Complementation transformation method

In the process of solving contradictory problems, the method of "complementing inefficiency by sufficiency" is commonly used, referred to as the complementation transformation method. "Exchanging object by object as a give-and-take trade" is complementation transformation of objects; the wolf is good at running but not clever enough, while the jackal is not good at running because of his short legs but is clever and broody, a wolf combined with a jackal to do evil by utilizing the advantage of each other is the origin of the Chinese idiom "A wolf working hand in glove with a jackal".

Next, we explain the complementation transformation of objects and complementation transformation of measures with different characteristics by taking matter-element as an example.

(1) Complementation transformation of matter

Given matter-elements $M_1 = (O_1, \quad c, \quad x_1), M_2 = (O_2, \quad c, \quad x_2)$,

If $T_1 M_1 = \{M_{11}, \quad M_{12}\} = \{(O_1', \quad c, \quad x_{11}), (O_2'', \quad c, \quad x_{12})\}$,

$T_2 M_2 = M_2 \oplus M_{11} = (O_2, \quad c, \quad x_2) \oplus (O_1', \quad c, \quad x_{11}) = (O, \quad c, \quad x) = M$

Then we call $T = T_2 T_1$ complementation transformation of matter.

(2) Complementation transformation of measures with different characteristics

Given matter-element

$$M = \begin{pmatrix} O, & c_1, & x_1 \\ & c_2 & x_2 \end{pmatrix}$$

If $T_1 x_1 = x_1 \Theta x$, and x_2 is correspondingly increased by x' , i.e. ${}_1T_2 x_2 = x_2 \oplus x'$, then the transformation $T = T_1 \wedge {}_1T_2$ that transforms *M* to

$$M' = \begin{pmatrix} O, & c_1, & x_1 \Theta x \\ & c_2 & x_2 \oplus x' \end{pmatrix}$$

is called the complementation transformation of measures with different characteristics.

When integrating enterprises, this kind of complementation transformation method is frequently used. For example, certain foreign companies established factories in China in cooperation with a Chinese company, and the Chinese party can utilize the advanced technology and equipment of the foreign party, while the foreign party can utilize the cheap labor capital and extensive market of the Chinese party.

It can be seen that there are many extension transformations to solve contradictory problems, and apart from the basic extension transformations, there are many operation methods of transformation. At application, we should conduct specific analysis of specific problems, and select the appropriate transformation method according to the different goals and conditions of the problem to be solved, to generate the strategy for solving the contradictory problem.

3.2.3 Conductive Transformation Methods

Because the correlation and implication between objects are ubiquitous, conductive transformation occurs frequently. The so-called conductive transformation method refers to the method to solve contradictory problem by consciously using conductive transformation.

There are the following two cases to solve contradictory problems by using conductive transformation methods:

(1) When the contradictory problem cannot be solved by direct transformation, it can be solved by using a conductive transformation method.

(2) In some cases, the contradictory problem can be solved by direct transformation, but the opportunity or effect of the transformation is not appropriate or the cost is huge, so we may consider using the conductive transformation method; if the effect of conductive transformation is better and its cost is less, the conductive transformation method can be used as the approach to solve the contradictory problem.

There are many conductive transformation methods, which can be divided according to the division of times of conductive into 1-order conductive transformation method and a multi-order conductive transformation method. Conductive transformation methods can be divided according to different objects of active transformation into conductive transformation caused by basic-element transformation, conductive transformation caused by dependent criterion transformation, conductive transformation caused by transformation of universe of discourse, and conjugate conductive transformation methods, etc.

Note: conductive transformation methods can cause new conductive transformation of other basic-elements while transforming the original contradictory problem to non-contradictory problems, causing occurrence of new contradictory problems, now we must adopt new transformation to solve the new problem.

The general steps of conductive transformation methods are as follows:

(1) As to the goal basic-element and condition basic-element of the problem, first judge whether the contradictory problem can be solved by direct transformation, if not, directly enter the next step; if the contradictory problem can be solved by direct transformation, judge whether the opportunity or effect of the transformation is suitable for the transformation, or judge the amount of cost of the transformation, if the opportunity or effect of the transformation is suitable, it ends; if it’s not suitable or the cost is huge, enter the next step.

(2) Form correlation tree by correlation analysis of condition basic-element of the problem, conduct divergence analysis of leaf basic-element, and implement active extension transformation of leaf basic-element. Because of correlation of basic-element and transmissibility of transformation, implication tree of conductive transformation will be inevitably formed, which will finally cause conductive transformation of root condition basic-element. If the contradictory problem is solved by this conductive transformation, it ends; otherwise enter

the next step.

(3) According to the actual situation of the problem, consider whether active transformation of dependent criterion can be implemented, if not, enter the next step; if yes, it will inevitably cause a conductive transformation of dependent functions. Judge whether the contradictory problem can be solved, if yes, it ends, otherwise enter the next step.

(4) According to the actual situation of the problem, consider whether the active transformation of universe of discourse can be implemented, if yes, it will inevitably cause a conductive transformation of dependent function. Judge whether the contradictory problem can be solved, if yes, it ends, otherwise enter the next step.

(5) According to the actual situation of the problem, judge whether active transformation of the main body (actor) that solves the contradictory problem can be implemented (when the goal or condition of the problem is an affair-element). Because of the correlation between the actor and universe of discourse, it will inevitably cause conductive transformation of universe of discourse. Judge whether the contradictory problem can be solved in the new universe of discourse, if yes, it ends, otherwise it's considered that this contradictory problem cannot be solved.

[Example 3.19] In 3.1, we have analyzed the marketing and planning problem of a certain toothpaste company, i.e. suppose:

$$A_1 = \begin{bmatrix} \text{buy}, & \text{dominating object}, & \text{toothpaste} \\ & \text{quantity}, & a \text{ tube/month} \end{bmatrix}$$

$$A_3 = \begin{bmatrix} \text{use}, & \text{dominating object}, & \text{toothpaste} \\ & \text{quantity}, & b\text{g/time} \\ & \text{times}, & 2 \text{ times/day} \end{bmatrix}$$

The conclusion obtained according to implication analysis method is $A_3 \Rightarrow A_1$, i.e. to let A_1 @, we simply need

A_3 @.

It's obvious that transformation φ_3 cannot be implemented directly:

$$\varphi_3 A_3 = \begin{bmatrix} \text{use}, & \text{dominating object}, & \text{toothpaste} \\ & \text{quantity}, & b'\text{g/time} \\ & \text{times}, & 2 \text{ times/day} \end{bmatrix} = A_3' \qquad (b' > b)$$

because the quantity of toothpaste used by each person at each time is the same. If certain transformation φ is found: $\varphi \Rightarrow \varphi_3$, then when φ @, we can let $\varphi_3 A_3 = A_3'$.

According to correlation analysis: M_0 = (toothpaste, use quantity, $b\text{g/time}$) ~ M =(toothpaste tube, caliber, d mm) , and $A_3 \Leftarrow M_0$, we make transformation φ:

$$\varphi M = (\text{toothpaste tube}, \ \text{caliber}, \ d'\text{mm}) = M' \quad (d' > d)$$

Then $\varphi \Rightarrow \varphi'$, let $\varphi' M_0$ = (toothpaste, use quantity, $b'\text{g/time}$) = M_0', and $\varphi' \Rightarrow \varphi_3$.

And then according to implication of affair-element transformation, there must be $\varphi_3 \Rightarrow \varphi_1$, to let

$$\varphi_1 A_1 = \begin{bmatrix} \text{buy}, & \text{dominating object}, & \text{toothpaste} \\ & \text{quantity}, & a' \text{ tube/month} \end{bmatrix} = A_1' \quad (a' > a)$$

i.e. by slightly enlarge the caliber of toothpaste tube, we can increase the quantity used by consumer at each time (it’s not necessary and impossible to increase the times of use each day), to increase the volume of purchase by consumers, i.e. the conductive effect is a'-a>0.

3.3 Conjugate Analysis and Conjugate Transformation Method

In 2.3 and 2.4, we have introduced the knowledge related to conjugate analysis and conjugate transformation. The method to comprehensively analyze matter and solve contradictory problems by conjugate analysis and conjugate transformation is referred to as conjugate analysis and conjugate transformation method. Because both conjugate analysis and conjugate transformation are pair analyses of real and imaginary, soft and hard, latent and apparent, negative and positive of the analysis object, so this method is also referred to as conjugate pair method.

Because matter-element is a kind of particular basic-element that describes matter by formalization, and among the matters of different classes, the measures of the corresponding characteristics of class matter and the individual matters in the class are different; we introduce the concepts of “class basic-element” and “individual basic-element”, for easy analysis and distinction.

Suppose $M_{\rm re}$, $M_{\rm im}$, $M_{\rm hr}$, $M_{\rm sf}$, $M_{\rm ng}$, $M_{\rm ps}$, $M_{\rm lt}$ and $M_{\rm ap}$ represent respectively real part basic-element and imaginary part basic-element, hard part basic-element and soft part basic-element, positive part basic-element and negative part basic-element, apparent part basic-element and latent part basic-element, collectively referred to as “class basic-elements”. As to the subclasses of them, in terms of enterprise resources, actually the real part matter-element $M_{\rm re}$ can be further divided into subclasses of capital, equipment, personnel, land, workshop, etc., referred to as “subclass matter-elements”, denoted as $M_{\rm re1}$, $M_{\rm re2}$, $M_{\rm re3}$, and $M_{\rm re4}$…… The basic-element formed by each individual of them is referred to as an “individual basic-element”, for example, an equipment P is represented by an “individual basic-element”. The relationship between them can be expressed as Figure 3.2:

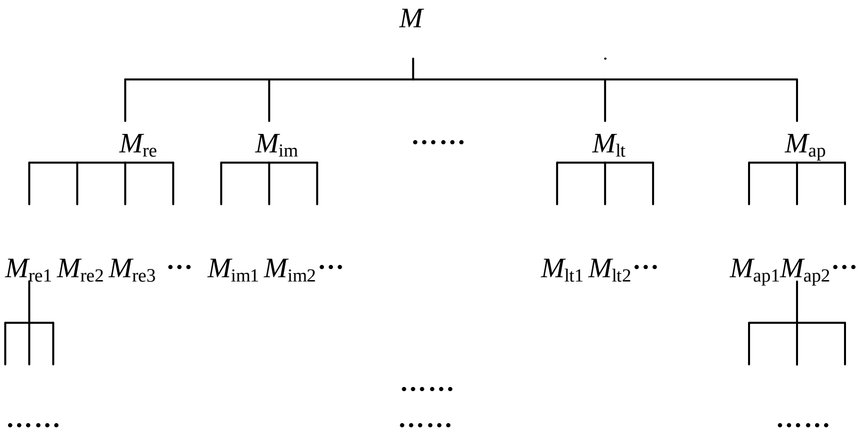


Figure 3.2 Relationship between Class Basic-element, Subclass Basic-element and Individual Basic-elements

In order to solve practical problems, we sometimes need to analyze and transform the class basic-elements formed by each conjugate part, and sometimes need to analyze and transform the individual basic-elements formed by each conjugate part.

Conjugate pairs include imaginary and real conjugate pairs, soft and hard conjugate pairs, latent and apparent conjugate pairs, and negative and positive conjugate pairs. This section mainly introduces the specific steps of imaginary and real conjugate pair methods, to which other methods are similar.

Next, we will introduce the specific steps to solve contradictory problems by imaginary and real pair method.

(1) If the object to be analyzed is a matter, first express it in the form of matter-element according to the characteristic involved by the problem and the characteristic required by condition;

(2) If it's determined that the characteristic involved by the problem and the characteristic required by the condition are imaginary or real characteristics, conduct imaginary and real conjugate analysis of the object to be analyzed, and list respectively its real part and imaginary part;

(3) Determine real part characteristic and corresponding real part matter-element M_{re};

(4) Determine imaginary part characteristic and corresponding imaginary part matter-element M_{im};

(5) As required, find the imaginary and real conjugate characteristic, and determine the corresponding conjugate matter-elements $\hat{M}_{re}$ and $\hat{M}_{im}$;

(6) Implement extension transformation of certain conjugate part matter-element or conjugate matter-element, and then determine the conjugate transformation according to the correlation of the conjugate part matter-element or conjugate matter-element;

(7) Determine the influence of active transformation or conjugate transformation on the realization of the goal, and if the contradictory problem can be solved by certain transformations, this transformation is the solution transformation of the contradictory problem. Otherwise, continue to implement transformations until the solution transformation is found.

[**Example 3.20**] The website N_1 achieved an annual profit of 100000 yuan last year, and plans to achieve the "goal of doubling the annual profit", try to study the solution to this contradictory problem by the conjugate pair method from imaginary resource to the real resource.

The goal of the website N_1 is

$$G = \left[\text{website } N_1,\quad \text{annual profit},\quad 200000 \text{ Yuan}\right],$$

the condition is $L = M_{im} \oplus M_{re}$, wherein

$$M_{im} = \begin{bmatrix} \text{website } N_1, & \text{daily hits}, & 100 \\ & \text{popularity}, & 1 \\ & \text{level of work}, & 2 \\ & \text{degree software innovation}, & 1 \end{bmatrix} = \begin{bmatrix} N_1, & c_1, & 100 \\ & c_2, & 1 \\ & c_3, & 2 \\ & c_4, & 1 \end{bmatrix},$$

$$M_{re} = \begin{bmatrix} \text{website } N_1, & \text{annual income from advertisement}, & 300000 \text{ Yuan} \\ & \text{actual annual profits}, & 100000 \text{ Yuan} \end{bmatrix} = \begin{bmatrix} N_1, & c_5, & 300000 \text{ Yuan} \\ & c_6, & 100000 \text{ Yuan} \end{bmatrix}$$

under condition L, goal G cannot be realized.

M_{re} is a real part condition and M_{im} is an imaginary part condition. It's obvious that the problem of the website is that its matter-element of imaginary part conditions cannot meet the requirement of realizing the real part goal. The contradictory problem of the real part is a superficial contradictory problem. By correlation analysis

$$\begin{cases} (N_1, & c_3, & v_3) \\ (N_1, & c_4, & v_4) \end{cases} \sim (N_1, \; c_2, \; v_2) \sim (N_1, \; c_1, \; v_1) \sim (N_1, \; c_5, \; v_5) \sim (N_1, \; c_6, \; v_6)$$

and according to the principle of imaginary and real conjugate transformation, the transformation of imaginary part matter-element will cause transformation of the real part matter-element that's correlated with it, i.e. we make active transformation of real part matter-element $\varphi = \varphi_1 \wedge \varphi_2$:

$$\varphi_1(N_1,\quad c_3,\quad v_3) = (N_1,\quad c_3,\quad v_3')$$
$$\varphi_2(N_1,\quad c_4,\quad v_4) = (N_1,\quad c_4,\quad v_4')$$

then there must be the following conductive transformations

$$\varphi \Rightarrow {}_{\varphi}T_1 \Rightarrow {}_1T_2 \Rightarrow {}_2T_3 \Rightarrow {}_3T_4$$

to let

$${}_{\varphi}T_1(N_1,\quad c_2,\quad v_2) = (N_1,\quad c_2,\quad v_2')$$

$${}_1T_2(N_1,\quad c_1,\quad v_1) = (N_1,\quad c_1,\quad v_1')$$

$${}_2T_3(N_1,\quad c_5,\quad v_5) = (N_1,\quad c_5,\quad v_5')$$

$${}_3T_4(N_1,\quad c_6,\quad v_6) = (N_1,\quad c_6,\quad v_6')$$

It can be seen that the change of level of work and degree of software innovation on the website will improve the website popularity, and the consequent increase of daily hits will cause an increase in advertisements, and finally lead to an increase in website profits.

The above process is a formalized description of solving contradictory problem by imaginary and real conjugate pair methods, and its practical meaning lies in: passionate works and software innovation can attract more attention, and the consequent more "number of hits" or "number of accesses" will let the website become the "famous website" or "well-known website" on the internet, and further become the predominant person or company on network, to achieve the goals of expanding publication of enterprise advertisements or product information, and collecting charges from the advertisement publishing enterprises or obtaining profits by online sales.

Many netizens are fond of publishing their favorite songs, drawings, articles and other good stuff on a network, to be viewed and downloaded by other netizens for free; many people modify and improve the free software similar to Linux without compensation, and even publish the source code without charge. The behaviors of these people aim to attract attention from the public, i.e. they are developing the "resource of attention" (imaginary resource). This is the method to achieve one's goal by using the imaginary resource.

Next we will explain the soft and hard conjugate pair method, latent and apparent conjugate pair method, and negative and positive conjugate pair method by examples respectively.

[**Example 3.21**] Certain enterprise N_1 expects to increase the goal profits of its golf course N_2 by utilizing the soft part (relations) of N_1, then, how to operate? The analysis by soft and hard conjugate pair method is as follows.

The goal of this problem is

$$G=\left[\text{enterprise } N_1,\quad \text{target annual profit},\quad 10 \text{ million Yuan}\right]$$

The conditions are

$$L_1=\left(\text{enterprise } N_1,\quad \text{annual profit},\quad 5 \text{ million Yuan}\right)\wedge\begin{bmatrix}\text{course } N_2, & \text{location}, & \text{certian suburb}\\ & \text{popularity}, & 4\\ & \text{level}, & 4\\ & \text{product type}, & \text{golf match or training}\\ & \text{type of customers}, & \text{celebrity}\vee\text{entrepreneur}\vee\text{political VIP}\vee\text{others}\\ & \text{ownership}, & \text{enterprise } N_1\end{bmatrix}$$

$$\wedge\begin{bmatrix}\text{artificial lake } N_3, & \text{location}, & \text{in } N_2\\ & \text{area}, & 10000\text{m}^2\\ & \text{function}, & \text{golf training course}\wedge\text{fishing site}\\ & \text{peripheral greening level}, & 4\\ & \text{ownership}, & \text{enterprise } N_1\end{bmatrix}\wedge\begin{bmatrix}\text{green land} N_4, & \text{location}, & \text{around } N_3\\ & \text{area}, & 20000\text{m}^2\\ & \text{function}, & \text{environment beautification}\\ & \text{ownership}, & \text{enterprise } N_1\end{bmatrix}$$

$$=L_{10}\wedge L_{11}\wedge L_{12}\wedge L_{13}$$

$$L_2=\begin{bmatrix}\text{cooperative relation}, & \text{antecedent}, & N_2\ \text{GM}\\ & \text{consequent}, & \text{entrepreneur}\\ & \text{degree}, & 3\end{bmatrix}\wedge\begin{bmatrix}\text{private relation}, & \text{antecedent}, & N_2\ \text{GM}\\ & \text{consequent}, & \text{political VIP}\\ & \text{degree}, & 5\end{bmatrix}$$

$$\wedge\begin{bmatrix}\text{service relation}, & \text{antecedent}, & N_2\ \text{GM}\\ & \text{consequent}, & \text{celebrity}\\ & \text{degree}, & 4\end{bmatrix}$$

$$=L_{21}\wedge L_{22}\wedge L_{23}$$

From the angle of soft and hard conjugate analysis, L_1 is the hard part condition, and L_2 is the soft part condition. To realize goal G, we first implement transformation of the hard part matter-element, such as active transformation of L_{13}

$$\varphi L_{13}=\varphi\begin{bmatrix}\text{green land} N_4, & \text{location}, & \text{around } N_3\\ & \text{area}, & 20000\text{m}^2\\ & \text{function}, & \text{environment beautification}\\ & \text{ownership}, & \text{enterprise } N_1\end{bmatrix}=\begin{bmatrix}\text{green land } N_4, & \text{location}, & \text{around } N_3\\ & \text{area}, & 20000\text{m}^2\\ & \text{function}, & \text{individualized usage}\\ & \text{ownership}, & \text{entrepreneur}\vee\text{celebrity}\end{bmatrix}=L'_{13}$$

Thus, by transferring (selling) the ownership of the green land, some entrepreneurs or celebrities will be attracted to accept the individualized usage of this green land, including constructing individualized villas, planting fruit trees and miniascape, etc. According to correlation, this transformation will inevitably cause a change within the relation between the general manager of enterprise N_2 and the entrepreneurs and celebrities who bought the green land, i.e. there must be conjugate transformation to let

$$
{}_{\varphi}T_1L_2 = L'_{21} \wedge L_{22} \wedge L'_{23}
$$

$$
= \begin{bmatrix} \text{cooperative} \wedge \text{service relation}, & \text{antecedent}, & N_2 \text{ GM} \\ & \text{consequent}, & \text{entrepreneur} \\ & \text{degree}, & 5 \end{bmatrix} \wedge \begin{bmatrix} \text{private relation}, & \text{antecedent}, & N_2 \text{ GM} \\ & \text{consequent}, & \text{political VIP} \\ & \text{degree}, & 5 \end{bmatrix}
$$

$$
\wedge \begin{bmatrix} \text{service relation}, & \text{antecedent}, & N_2 \text{ GM} \\ & \text{consequent}, & \text{celebrity} \\ & \text{degree}, & 5 \end{bmatrix}
$$

and there is further conductive transformation

$$
{}_1T_2L_{11} = \begin{bmatrix} \text{course } N_2, & \text{location}, & \text{certian suburb} \\ & \text{popularity}, & 5 \\ & \text{level}, & 4 \\ & \text{product type}, & \text{golf match or training} \wedge \text{villa} \\ & \text{type of customers}, & \text{celebrity} \vee \text{entrepreneur} \vee \text{political VIP} \vee \text{others} \\ & \text{ownership}, & \text{enterprise } N_1 \end{bmatrix} = L'_{11}
$$

$$
{}_2T_3L_{10} = \left(\text{enterprise } N_1, \quad \text{annual profit}, \quad 10 \text{ million Yuan}\right) = L'_{10}
$$

to realize the enterprise’s goal.

It’s meaning lies in: the association with many political VIPs and entrepreneurs that are established through holding celebrity golf matches, and the green land N_4 by the side of one artificial lake N_3 is sold by utilizing the excellent environment and geographical location of the course, to let the “meadow” by the side of the lake become the “land of real estate” for the clients to design villas according to their requirements, and construction of villas by the clients will further deepen their relation with the course, bringing more business opportunities for operating the course, to let the course obtain more profits.

[**Example 3.22**] In order to avoid the intense competition of the market of old products and explore new markets, after analyzing public demands, an enterprise manufacturing pot products decides to develop a new product that complies with the public demand for “nonstick pans” and is manufactured by the material that is harmless to the human body, to improve the enterprise competitiveness. Now, we analyze the enterprise by latent and apparent conjugate pair methods.

Suppose the enterprise is O_m, and its developing new-concept product or new product model is $N_0(t)$. It can be known from latent and apparent conjugate analysis that before enterprise production (i.e. moment t_0), $N_0(t_0)$ is the latent matter of the enterprise product, as a part of the latent part of the enterprise, i.e.

$$
O_m = \text{lt}(O_m) \oplus \text{ap}(O_m) \oplus \text{mid}_{\text{lt-ap}}(O_m)
$$

$N_0(t_0)$ is a part of $\text{lt}(O_m(t_0))$. Suppose this latent part matter-element before production (i.e. matter-element at moment t_0) is

$$M_{\text{lt}}(N_0(t_0)) = \begin{bmatrix} N_0(t_0), & \text{name}, & \text{bionic nonstick pan} \\ & \text{function}, & \text{dish frying} \vee \text{pancake baking} \vee \text{rice cooking} \\ & \text{feature}, & \text{smoke free} \wedge \text{nonstick} \\ & \text{material}, & \text{smoke free} \wedge \text{nonstick} \end{bmatrix}$$

After the new product is appraised and the patent is applied, it's discovered through market analysis and feasibility research that the market of the bionic nonstick pan is very extensive, and measures can be taken to make the above latent part matter-element (i.e. matter-element at moment t_1) apparent, i.e.

$$\varphi M_{\text{lt}}(N_0(t_0)) = M_{\text{ap}}(N_0(t_1)),$$

transformation φ transforms this latent part matter-element of the enterprise to apparent part matter-element:

$$M_{\text{ap}}(N_0(t_1)) = \begin{bmatrix} N_0(t_1), & \text{name}, & \text{bionic nonstick pan} \\ & \text{function}, & \text{dish frying} \vee \text{pancake baking} \vee \text{rice cooking} \\ & \text{feature}, & \text{smoke free} \wedge \text{nonstick} \\ & \text{material}, & \text{smoke free} \wedge \text{nonstick} \\ & \text{patent no.}, & \text{a} \end{bmatrix}$$

i.e. production of bionic nonstick pan. While the new product must be provided with a new production workshop or a new production line, i.e. the implementation of φ will inevitably cause the enterprise to construct a new production workshop or new production line $N_1(t_1)$, so as to cause the generation of conjugate transformation of the apparent part of the enterprise, i.e. we have $\varphi \Rightarrow {}_{\varphi}T_1$, to let

$${}_{\varphi}T_1 M_{\text{ap}}(O_m) = M'_{\text{ap}}(O_m)$$

Both $N_0(t_1)$ and $N_1(t_1)$ are part of ap($O_m(t_1)$). While the increase of production line will inevitably cause an increase of funds input by the enterprise, the enterprise can obtain income from the new product only after the new product is manufactured and launched on the market. In other words, the occurrence of this conjugate transformation will lead to a series of conductive transformations. Only after the enterprise obtains new profits by utilizing this product can we prove that this latent and apparent conjugate transformation is successful.

[**Example 3.23**] The waste gas N_1, waste water N_2 and waste dreg N_3 produced by certain enterprise N during the process of production, in terms of enterprise profits (denoted as characteristic c), are the negative part of the enterprise, forming three negative part matter-elements

$$M_{\text{ng}_c}(N_1) = \begin{bmatrix} \text{waste gas } N_1, & \text{main component}, & \text{gas} \\ & \text{form}, & \text{gas} \\ & \text{combustibility}, & \text{good} \\ & \text{color}, & \text{black} \\ & \text{usage}, & \text{non} \end{bmatrix}$$

$$M_{\mathrm{ng}_c}(N_2)=\begin{bmatrix} \text{waste water } N_2, & \text{main component}, & \text{hazardous substance} \\ & \text{form}, & \text{liquid} \\ & \text{color}, & \text{brownish-black} \\ & \text{separability}, & \text{strong} \\ & \text{usage}, & \text{non} \end{bmatrix}$$

$$M_{\mathrm{ng}_c}(N_3)=\begin{bmatrix} \text{waste dreg } N_3, & \text{main component}, & \text{silicon oxide} \\ & \text{form}, & \text{solid} \\ & \text{color}, & \text{offwhite} \\ & \text{usage}, & \text{non} \end{bmatrix}$$

These "three wastes" become a heavy burden of the enterprise. To solve these contradictory problems, we make transformations respectively according to the characteristics of these three negative part matter-elements:

$\varphi_1 N_1=\{N_1',\ N_1''\}$, i.e. N_1 is collected to separate out fuel gas N_1';

$\varphi_2 N_2=\{N_2',\ N_2''\}$, i.e. N_2 is not discharged but disposed in full closed line, to filter industrial water N_2';

$\varphi_3 N_3=N_3\oplus\text{adhesive}\oplus\text{ingredient}=N_3'$, i.e. N_3 is added with adhesive and other ingredients, to form new material N_3'. Then the following three positive part matter-elements are formed:

$$_{\varphi_1}T_1 M_{\mathrm{ng}_c}(N_1)=M_{\mathrm{ps}_c}(N_1')=\begin{bmatrix} \text{fuel gas } N_1', & \text{main component}, & \text{gas} \\ & \text{form}, & \text{gas} \\ & \text{combustibility}, & \text{good} \\ & \text{color}, & \text{non} \\ & \text{usage}, & \text{boiler burning} \wedge \text{electricity generating} \end{bmatrix}$$

$$_{\varphi_2}T_2 M_{\mathrm{ng}_c}(N_2)=M_{\mathrm{ps}_c}(N_2')=\begin{bmatrix} \text{regenerated water } N_2', & \text{main component}, & \text{harmless clear water} \\ & \text{form}, & \text{liquid} \\ & \text{color}, & \text{non} \\ & \text{usage}, & \text{water for production} \end{bmatrix}$$

$$_{\varphi_3}T_3 M_{\mathrm{ng}_c}(N_3)=M_{\mathrm{ps}_c}(N_3')=\begin{bmatrix} N_3', & \text{main component}, & \text{silicon oxide} \\ & \text{form}, & \text{solid} \\ & \text{color}, & \text{offwhite} \\ & \text{usage}, & \text{bricks making} \end{bmatrix}$$

The "three wastes" are changed into "three treasures" through these three transformations, so the enterprise saves tremendous cost and obtains significant profits, i.e. the negative part of the enterprise is transformed to a positive part of the enterprise. The specific practice is: waste gas is collected and separated, to be utilized as fuel gas to burn the boiler and generate electricity, decreased the fuel cost of the enterprise; full closed disposal and recycling system of waste water is constructed, and the cleaned harmless water is reused as industrial water, saved water consumption of the enterprise; the waste dreg is used as the raw material for bricks, saved the cost for purchase of bricks to expand the workshop, and the redundant bricks can also be sold as products for the enterprise to obtain profits.

3.4 Extension Set Method

Set is the method to describe the classification and recognition of objective things by the human brain. Objective things are complicated and ever-moving and changing. Therefore, the recognition and classification of objective things by human thinking is not in a single mode, but in multiple modes. Consequently, the set theory that describes this kind of recognition and classification should not be unique, but diversified.

In 2.6, we introduced the fundamental knowledge of extension set, in this section, we'll introduce the methods of extension classification, extension clustering and extension recognition by using the nature of classification and recognition of the extension set.

3.4.1 Extension Classification Method

The extension classification method is based on the classification method of transformations. It's significantly different from the classification method based on the classical set. For example, an enterprise is required to process certain work pieces by specification (diameter) of <50-0.1, 50+0.1>(mm) , and now there is a batch of processed work pieces that can be classified into conforming and nonconforming products by the classification method of the classical set, i.e. the products with diameter between [49.9, 50.1] are conforming and those with diameter less than 49.9 and more than 50.1 are nonconforming. However, the nonconforming products with a diameter less than 49.9 are scraps, and the nonconforming products with a diameter of more than 50.1 are reworks. The reworks can be transformed to conforming products after reprocessing; the nonconforming products with a diameter less than 49.9 cannot be transformed to conforming products in the limitation of lathe processing only. It's obvious that, among the nonconforming products, the scraps and reworks are nonconforming products with a different nature, as shown in Figure 3.3.

Contrarily, if "reprocessing" is transformed to "electroplating", the work pieces with a diameter of more than 50.1 become scraps, and those with a diameter less than 49.9 are reworks. It's obvious that this classification depends on the adopted transformation, and the different transformation corresponds to the different classification. This kind of classification problem is tremendous in the real world, so this kind of classification method based on transformation must be studied.

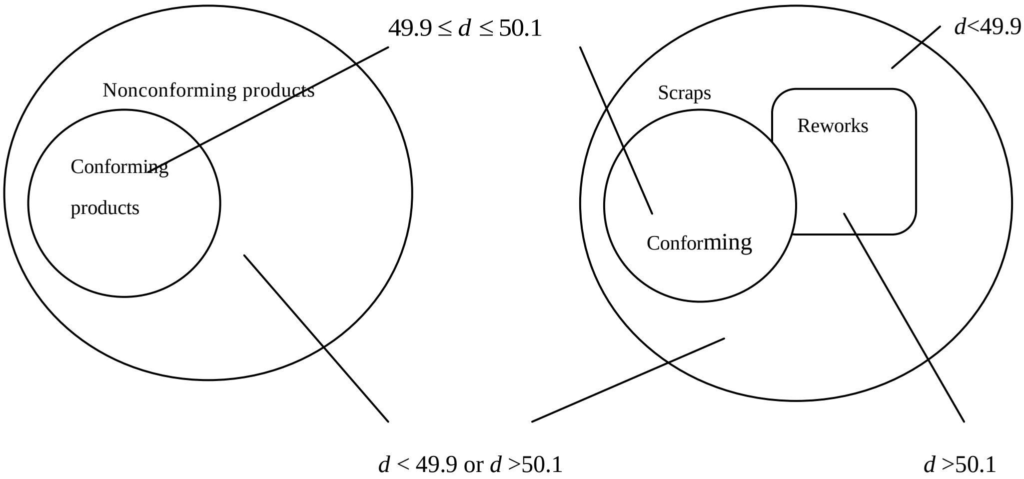


Figure 3.3 Classical Classifications and Transformable Classifications of the Universe of Discourse of Work pieces

According to the definition of an extension set, a given extension transformations should correspond to the classification of an extension set, which can divide the extension set into five parts of positive extensible fields, negative extensible fields, positive stable fields, negative stable fields, and extension boundaries, and divide also the universe of discourse into five parts, corresponding to the five parts of extension transformation of the elements in the universe of discourse, see 2.6. This kind of classification method based on the definition of extension set is referred to as an extension classification method.

It can be seen that an extension classification method is based on extension transformation, including the extension classification based on transformations of elements in the universe of discourse, extension classifications about transformations of dependent criteria, and extension classifications based on transformations of the universe of discourse.

The general steps of extension classification methods are as follows:

1. The object to be classified as a whole is used as a universe of discourse U, as to any one extension transformation T=(T_k, T_u), establish extension set on U:

$$\tilde{E}\,(T\,)=\{\,(u,y,y')\mid u\in U,\, y=k(u)\in I;\, T_u u\in U,\, y'=T_k\, k(T_u\, u)\in I\,\}$$

wherein y=k(u) is dependent function, which indicates the degree that the object u in universe of discourse U has certain nature. According to the different requirements of indexes in practical problem, y=k(u) can be in the different forms of elementary dependent function, simple dependent function, discrete dependent function, or interval dependent function, etc.

2. When T=(T_k, T_u)=(e,e), i.e. the transformation is unitary transformation, calculate the dependent function value of each object, and classify the universe of discourse according to the dependent function value into:

$$V_+=\{\,u\mid u\in U,\quad k(u)>0\,\},$$

$$V_-=\{\,u\mid u\in U,\quad k(u)<0\,\},$$

$$V_0=\{\,u\mid u\in U,\quad k(u)=0\,\},$$

which are called respectively positive field, negative field and zero boundary of universe of discourse U. This is a classification of universe of discourse, which is definite as to definite dependent function.

3. When T=(T_k, T_u)≠(e,e), for a definite extension transformation, calculate the dependent function value of each transformed object, and classify the universe of discourse according to the dependent function value into:

$$\underset{\bullet}{V}_+(T)=\{\,u\mid u\in U,\, y=k(u)\leqslant 0\,;\, T_u u\in U,\, y'=T_k\, k(T_u u)>0\}$$

is called positive extensible field of the universe of discourse U about transformation T;

$$\underset{\bullet}{V}_-(T)=\{\,u\mid u\in U,\, y=k(u)\geqslant 0\,;\, T_u u\in U,\, y'=T_k\, k(T_u u)<0\}$$

is called negative extensible field of the universe of discourse U about transformation T;

$$V_+(T)=\{\,u\mid u\in U,\, y=k(u)>0\,;\, T_u u\in U,\, y'=T_k\, k(T_u u)>0\}$$

is called positive stable filed of the universe of discourse U about transformation T;

$$V_{-}(T)=\{ u \mid u \in U, y=k(u)<0 ; T_u u \in U, y'= T_k k(T_u u)<0\}$$

is called negative stable field of the universe of discourse U about transformation T;

$$V_0(T)= \{ u \mid u \in U, T_u u \in U, y'= T_k k(T_u u)=0\}$$

is called extension boundary of the universe of discourse U about transformation T.

This is a classification of the universe of discourse about extension transformation, which is definite as to definite extension transformation and dependent function.

4. According to the above classification method, the universe of discourse can be classified into 5 parts. Thus, any one object in the universe of discourse, after an extension transformation is given, must belong to a certain one of the above 5 classes. Extension classification is completed.

5. Similarly, in case another extension transformation is implemented, calculate the dependent function value of each transformed object, which corresponds to a new extension classification.

6. According to the requirements of different measuring ranges of dependent function values, the above classification can be further classified, such as

$$V_{\cdot +}(T)= \{ u \mid u \in U, y=k(u) \leqslant 0 ; T_u u \in U, y'= T_k k(T_u u)>0\}$$

If it's required that the dependent function values after transformation among <0,1>, <1, 5>, <5, +∞) should be classified into the same class, these three classes are sets as follows:

$$V_1(T)= \{ u \mid u \in U, y=k(u) \leqslant 0 ; T_u u \in U, y'= T_{\mathrm{k}} k(T_{\mathrm{u}} u) \in <0,1>\}$$

$$V_2(T)= \{ u \mid u \in U, y=k(u) \leqslant 0 ; T_u u \in U, y'= T_{\mathrm{k}} k(T_{\mathrm{u}} u) \in <1,5>\}$$

$$V_3(T)= \{ u \mid u \in U, y=k(u) \leqslant 0 ; T_u u \in U, y'= T_{\mathrm{k}} k(T_{\mathrm{u}} u) \in <5, +\infty>\}$$

7. If transformation is implemented on the universe of discourse U of the objects to be classified, make $T_U U=U'$, which corresponds to a kind of extension classification of the new universe of discourse, and then repeat the steps 1-6.

[Example 3.24] The Human Resources Department of a company is required to conduct classification management of all employees, and the original classification method is by departments, professional titles, educational backgrounds, technical types, and ages, etc. Because of the characteristics of hi-tech products of modern enterprise production, the relations between each department and each type of work become increasingly closer day by day. Therefore, classification management of human resources should also take into consideration its changeability. With increasingly intense market competitions, the old products of the company cannot meet the market requirements, so it's decided to change the line of production to certain hi-tech products. The extension classification method of human resources of the company by using extension classification method is given as follows.

Suppose the universe of discourse formed by all employees of the company is U. For any one employee matter-element $M \in U$,

$$M = \begin{bmatrix} O, & \text{department } c_1, & v_1 \\ & \text{professional title } c_2, & v_2 \\ & \text{technical type } c_3, & v_3 \\ & \text{educational background } c_4, & v_4 \\ & \text{age } c_5, & v_5 \end{bmatrix}$$

Suppose the degree that certain technical levels complies with the company's requirement for developing certain hi-tech product is $y=k(M)$, we can establish an extension set

$$\tilde{E}\,(T)=\{\,(M,y,y')\mid M\in U,\ y=k(M)\in I;\ T_M M\in U,\ y'=T_k\, k(T_M M)\in I\,\}$$

(1) When no transformation is implemented, i.e. $T=(T_k,\ T_M)=(e,e)$, the employees of the company can be classified into three classes:

$V_-=\{\,M\mid M\in U,\ k(M)<0\,\}$ indicates all employees whose certain technical level does not comply with the company's requirement for developing certain hi-tech products;

$V_+=\{\,M\mid M\in U,\ k(M)>0\,\}$ indicates all employees whose certain technical level complies with the company's requirement for developing certain hi-tech products;

$V_0=\{\,M\mid M\in U,\ k(M)=0\,\}$ indicates all employees whose certain technical level is in critical state, i.e. both complies and does not comply with it.

Through above classification, it's discovered the qualified employees as a whole V are still not enough for the task of developing the hi-tech product. Therefore, the unqualified employees must be trained, i.e. classification under transformation should be repeated to organize a new development team.

(2) Conduct technical training for the employees whose certain technical level does not comply with the requirement, i.e. make transformation:

$$T_M M = \begin{bmatrix} O, & \text{department } c_1, & v_1 \\ & \text{professional title } c_2, & v_2 \\ & \text{technical type } c_3, & v_3' \\ & \text{educational background } c_4, & v_4 \\ & \text{age } c_5, & v_5 \end{bmatrix} = M'$$

Organize examination after training to determine the degree of qualification of the employees, i.e. according to the value of $y'=k(T_M M)$, classify the company's employees into four classes:

$V_+=\{\,M\mid M\in U,\ k(M)>0\,\}$ indicates the originally qualified employees as a whole;

$V_{\cdot+}(T)=\{\,M\mid M\in U,\ y=k(M)\leqslant 0;\ T_M M\in U,\ y'=k(T_M M)>0\}$, indicate the employees as a whole that were originally unqualified or in a critical state but are transformed to be qualified after training;

$V_-(T)=\{\,M\mid M\in U,\ y=k(M)<0;\ T_M M\in U,\ y'=k(T_M M)<0\}$, indicate the employees as a whole that were originally unqualified but are still unqualified after training;

$V_0(T)$= { M | $M \in U$, $T_M M \in U$, $y' = k(T_M M)=0$}, indicates the employees as a whole that are in a critical state after training, no matter if they were originally qualified or not.

Under the above transformation T_M, the qualified employees as a whole is transformed to $V \cup \underset{\cdot}{V}_{+}$, and if these employees are enough for the task of developing the hi-tech product, the classification is completed. If the number of employees is more than required, the employees for the task should be selected from all of the qualified employees according to the big or small order of their dependent function values.

(3) For the employees as a whole that are not selected after above classification U_1, the company should consider the problems of job transfer and settlement. The company considers establishing a cultural service department, for which the original dependent criterion is not suitable, so we should first conduct transformation of dependent criterion, i.e. make $T_k\ k= k'$, such as classification of employees in U_1 by considering their sociability and cultural degree. The employees in U_1 can be classified into three classes:

$\underset{\cdot}{V}_{+}(T)$= { M | $M \in U_1$, $y=k(M) \leqslant 0$, $y' = k'(M)>0$} indicates the employees as a whole that were unqualified for the original requirement or in a critical state but become qualified after transformation of criterion;

$V_{-}(T)$= { M | $M \in U_1$, $y=k(M)<0$, $y' = k'(M)<0$} indicates the employees as a whole that were unqualified for the original requirement and are still unqualified after transformation of criterion;

$V_0(T)$= { M | $M \in U_1$, $y=k(u)=0$, $y' = k'(u)=0$} indicates the employees as a whole that were originally in a critical state and are still in a critical state after transformation of criterion.

For unified deployment and reasonable settlement of the company's employees, the new criterion can be used to classify the employees in U that are qualified for the original requirement into two classes:

$\underset{\cdot}{V}_{-}(T)$={ M | $M \in U$, $y=k(M) \geqslant 0$, $y' = k'(M)<0$} indicates the employees as a whole that were qualified for the original requirement or in critical state but become unqualified for the new requirement after the transformation of criterion;

$V_{+}(T)$={ M | $M \in U$, $y=k(M)>0$, $y' = k'(M)>0$} indicates the employees as a whole that were qualified for the original requirement and are still qualified for the new requirement after transformation of criterion.

Under the above transformation T_k, the employees as a whole that are qualified for the new requirement are transformed to $V_{+}(T) \cup \underset{\cdot}{V}_{+}(T)$, wherein, the employees in $V_{+}(T)$can act as optional personnel, for example, any employee among them is suitable for the post of manager of the cultural service department can be deployed to the department.

(4) If the requirement still cannot be met after the above classification, we can also adopt the method of transformation of universe of discourse, i.e. we make $T_U U=U'$, and this transformation can further cause new classifications of employees. For example, in the case of criterion unchanged, the extension transformation of the universe of discourse, by recruiting some external hi-tech personnel to participate in the research team, or

recruiting external part-time technicians, etc. can change the classification, and generate a new combination of the team. This is omitted herein.

3.4.2 Extension Clustering Method

Clustering, as a commonly used method to analyze and understand objects, is a process of dividing the physical or abstract object set into multiple groups. The group generated by clustering is called cluster, i.e. a cluster is a set of data objects. By clustering, we aim to have higher similarities between any two objects inside the generated cluster, and higher dissimilarities between two objects that belong to different clusters.

The main difference between clustering and classification lies in: the number of classes to be generated is unknown before clustering, while classification is generally to classify the elements in the universe of discourse into each class in the situation that the number of classes to be classified is specific.

Clustering analysis, as a critical technology in data analysis, has extremely extensive applying fields, such as data mining, statistics, machine learning, pattern recognition, biology, spatial database technology, electronic commerce, etc.

From the viewpoint of statistics, clustering analysis is a method of data modeling to simplify the data. As a main branch of multivariate statistical analysis, the study on clustering analysis has been conducted for many years, mainly focusing on the clustering methods that are based on distance and similarity. Traditional clustering analysis methods include system clustering method, decomposition method, addition method, dynamic clustering method, ordered sample clustering, overlapped clustering and fuzzy clustering, etc. The clustering analysis tool that adopts *k*-mean value and *k*-medoid algorithm has been added into many famous statistical analysis software packages such as SPSS and SAS, etc.

From the viewpoint of machine learning, cluster is equivalent to the hidden mode, and clustering is the unsupervised learning process that searches for clusters.

From the viewpoint of practical application, clustering analysis is one of the main tasks of data mining. In a data mining field, the main study is on the efficient and practical clustering analysis algorithm that is oriented to large databases and data warehouses. Data mining concerns the following characteristics of clustering algorithm: capacity for processing different types of properties, expandability for large data set, capacity for processing higher-dimensional data, capacity for finding the cluster with arbitrary shape, capacity for processing outlier or “noise” data, insensitivity to data sequence, dependence on priori knowledge and customized parameter, interpretability and practicability of clustering results, and clustering based on constraint, etc. The main clustering methods for data mining include classification methods, hierarchy methods, methods based on density, methods based on grids, and method based on models, etc.

Clustering is a kind of unsupervised classification. The traditional clustering analysis is a kind of hard classification that strictly classifies each classification object into certain classes, reflecting the either-or property, so this kind of classification has explicit class boundaries. Nevertheless, the boundaries between things are usually inexplicit, and there are numerous phenomena of fuzzy classifications, to which fuzzy set theory provides a beneficial mathematical tool. In 1969, Ruspini proposed the concept of fuzzy classification, and made the pioneer work regarding fuzzy clustering analysis. Many fuzzy clustering methods based on the concept of fuzzy classification have been proposed, such as transitive closure method, maximal tree method, netting method, fuzzy clustering method based on perturbation, and fuzzy C-mean value method, etc. Fuzzy clustering reflects the degree of uncertainty that an object belongs to different classes, and represents the intermediary property of object generic, more objectively reflecting the real word.

Another kind of classification that changes with the implementation of transformation is extension clustering analysis. The objects in the universe of discourse of extension clustering are basic-elements, and the "location" of basic-elements in the universe of discourse is determined by the qualified degree of each basic-element – dependent function value of the basic-element, for clustering of basic-elements in the universe of discourse.

The general steps of extension clustering are as follows:

1. Suppose the set constituted by the objects to be clustered is the universe of discourse U, denoted by $U=\{O_1,O_2,\cdots,O_n,\}$, and expresses each object by basic-elements according to the conditions of the practical problem, to form a universe of discourse of basic-elements, denoted by

$$U_B=\{B_i\ \Big|B_i=\begin{bmatrix} O_i, & c_{i1}, & v_{i1} \\ & c_{i2}, & v_{i2} \\ & \vdots & \vdots \\ & c_{im}, & v_{im} \end{bmatrix}, i=1,2,\cdots,n,\}$$

2. According to the requirements for clustering by the practical problem select evaluation characteristic and conduct clustering.

(1) In case of single evaluation characteristic c, and measuring the range in the form of nest of intervals, establish dependent function $k(x_i)=k(c(B_i))$ of basic-element on the qualified degree of c. For the various forms of dependent function, see also2.7. Respectively calculate the dependent function value of each basic-element as $k(x_i), i=1,2,\cdots,n$.

As to any extension transformation T=(T_U, T_K, T_B), B can be any basic-element in U_B, and we establish extension set on U_B:

$$\tilde{E}(T)=\{(B,y,y')\mid B\in U_B, y=K(B)\in I; T_BB\in T_UU_B, y'=T_K K(T_B B)\in I\}$$

wherein y=K(B)=k(x) is a dependent function that indicates the degree that the object B in the universe of discourse U_B has certain property.

1) If the extension transformation T is not implemented, cluster all basic-elements according to the size of dependent function values, into 3 classes at most;

2) If the extension transformation of a basic-element (T_B) is implemented, cluster all basic-elements according to the size of the dependent function values of the transformed basic-elements, into 5 classes at most;

3) If the extension transformation of a dependent function (T_K) is implemented, cluster all basic-elements according to the size of the dependent function values of the basic-elements after transformation, into 5 classes at most;

4) If the extension transformation of an universe of discourse (T_U) is implemented, establish new dependent functions for the basic-elements in the new universe of discourse (sometimes the original dependent functions can be applied, depending on the specific problem), and calculate the size of the dependent function values, to

cluster the basic-elements in the new universe of discourse.

(2) In case of multiple evaluation characteristics $C=\{c_1,c_2,\cdots,c_s,\}$, and measuring the range in the form of the nest of an interval, first establish the dependent function of basic-elements on the qualified degree of each evaluation characteristic c_i

$$k(x_{ji})=k(c_j(B_i)), j=1,2,\cdots,s; i=1,2,\cdots,n$$

1) If the weights of each evaluation characteristic are $\alpha=\{\alpha_1,\alpha_2,\cdots,\alpha_s,\}$, respectively calculate the comprehensive dependent degree of each basic-element as

$$K(B_i)=\sum_{j=1}^{s}\alpha_j k(x_{ji}), i=1,2,\cdots,n$$

2) If it's required that the basic-element is considered qualified only when all evaluation characteristics are qualified, the comprehensive dependent degree of each basic-element is

$$K(B_i)=\mathop{\wedge}_{j=1}^{s} k(x_{ji}),\ i=1,2,\cdots,n$$

3) If the basic-element is qualified when any one evaluation characteristic is qualified, the comprehensive dependent degree of each basic-element is

$$K(B_i)=\mathop{\vee}_{j=1}^{s} k(x_{ji}),\ i=1,2,\cdots,n$$

For any extension transformation T=(T_U, T_K, T_B), establish extension set on U_B:

$$\tilde{E}\,(T)=\{\ (B,y,y')\mid B\in U_B,\ y=K(B)\in I;\ T_B B\in T_U U_B,\ y'=T_K\,K(T_B B)\in I\ \}$$

wherein $y=K(B)$ is a comprehensive dependent function that indicates the degree that the object B in the universe of discourse U_B has certain property.

1) If the extension transformation T is not implemented, cluster all basic-elements according to the size of the comprehensive dependent degree k_i, into 3 classes at most;

2) If the extension transformation T_B is implemented, cluster all basic-elements according to the size of the comprehensive dependent degree of basic-elements after transformation, into 5 classes at most;

3) If the extension transformation T_K is implemented, cluster all basic-elements according to the size of the comprehensive dependent degree of basic-elements after transformation;

4) If the extension transformation T_U is implemented, establish new dependent functions for the basic-elements in the new universe of discourse (sometimes the original dependent functions can be applied, depending on the specific problem), and cluster the basic-elements in the new universe of discourse according to the size of comprehensive dependent degree.

It's obvious that different transformation corresponds to different clustering. Because the nature, human society and economic environment are ever-changing, the characteristics, standard and range of clustering are ever-changing. Extension clustering methods appears exactly to adapt to the clustering under this kind of transformation.

3.4.3 Extension Recognition Method

Because environments, systems and elements are ever-changing, recognition of things results in different conclusions with these changes. Therefore, we should study the recognition methods under transformation – extension recognition, especially the object recognition method "transforming negative to positive" and "positive to negative". On the other hand, we should also study the transformation method that transforms unrecognizable problems to recognizable ones.

1. Study object of extension recognition

Recognition is a method commonly used by people. For example, we recognize whether the coming person is Jack, whether a creature is an insect, and whether the disease suffered by someone is cerebral thrombosis, etc. These problems can be generally concluded into three types:

a) Known O_0, recognize whether O is O_0;

b) Known O and class A, recognize whether O belongs to A;

c) Known O and class $A_1, A_2, \ldots, A_n$, recognize to which class O belongs.

It's obvious that the first type is a special case of the second type, and the third type is an extension of the second type.

We frequently come across the following problems in recognition activities: How to recognize a disguised criminal suspect? Whether the insect with a broken leg is an insect (to be an insect it must have 6 legs), Should mutated bacteria belong to which category? How to recognize a syndrome? Etc.

Extension recognition is to recognize things from the angle of transformation, by utilizing the thinking of extension set, and study how to change the unrecognizable object to recognizable by transformation, including:

① How to have certain characteristics of a thing changed by transformation, so as to recognize it;

② How to determine the truthfulness/falseness of acquired information by transformation;

③ How to acquire more information by transformation and acquired information, so as to determine the truthfulness/falseness of things or the degree that things belong to a certain category.

Transformations of extension recognition can be divided into three types:

① Transformation of an object and object-describing basic-element;

② Transformation of recognition criteria;

③ Transformation of field of objects (universe of discourse).

In summary, the core study by extension recognition is a study on and recognition of the objects and methods that "transform positive to negative" and "transform negative to positive".

The study on extension recognition has been started before long, which is still a virgin land to be cultivated.

This book provides elementary introduction subject to the current rudimentary knowledge and existing study results, while deepened discussion is to be explored by the readers with efforts.

2. Basic concepts

In recognition activities, when coming across unrecognizable problems, people usually adopt the method of transformation to transform the unrecognizable problem to a recognizable problem. For example, to recognize whether the Golden Crown is adulterated, weight is no use, it should be transformed to the problem of calculating the volume of the Golden Crown, to recognize the truthfulness and falseness of the Golden Crown by calculating the volume of the Golden Crown. When the category of a certain ore cannot be recognized by a physical method, it can be recognized by a chemical method after transformation by geologists. This kind of method that transforms the unrecognizable to recognizable is a subject to be earnestly studied as well.

To study extension recognition methods, we should first introduce several basic concepts.

(1) Present matter, past matter and future matter

Given matter $O(t)$, if $t=t_0$ indicates the present time, we call $O(t_0)$ present matter, $O(t)(t<t_0)$ past matter, and $O(t)(t>t_0)$ future matter.

(2) Key basic-element

Any matter is constituted by many components, such as a pig that has legs, head, body and tail, while to recognize whether it’s a pig; the key is to check its nose. To recognize whether a person is Jack, the key is to check its face or fingerprint, and to analyze its DNA structure today. To recognize an insect, check if it has six legs. Considered from systematicness of a matter, its hard part can be expressed as $\mathrm{hr}(O)=\{O_1,O_2,...O_n\}$. In case of a key part of matter, the key part of *O* is denoted by O_h.

Matters are also divided into class matter and individual matter. As to class matter *A*, the key part that determines whether *O* belongs to *A* is denoted by $O_h(A)$.

Key part is determined by professional knowledge or historical data, and key parts may be multiple, denoted by $\{O_{hi}\}, i=1,2,..,m$.

To determine whether an object belong to a certain class of matter by its key parts, we must consider its key characteristic c_h. If c_h is multiple, it’s denoted by $\{c_{hi}\}, i=1,2,...,n$. Key characteristics are also determined by professional knowledge or historical data. When the measure of the recognized object *O* about key characteristic c_h is v_h, we call $B_h=(O_h,\ c_h,\ v_h)$ key basic-element. (c_h,v_h) is key characteristic element.

When key characteristics are multiple, the key basic-element is multi-dimensional basic-element, denoted by

$$B_h=\begin{bmatrix} O_h, & c_{h1}, & v_{h1} \\ & c_{h2}, & v_{h2} \\ & \vdots & \vdots \\ & c_{hn}, & v_{hn} \end{bmatrix}$$

When key parts are multiple, i.e. $\{O_{hi}\}$, $i=1,2,...,m$, then there are m key basic-elements:

$$B_{hi}=\begin{bmatrix} O_{hi}, & c_{hi1}, & v_{hi1} \\ & c_{hi2}, & v_{hi2} \\ & \vdots & \vdots \\ & c_{hn_i}, & v_{hn_i} \end{bmatrix},(i=1,2,...m)$$

(3) Special basic-element and general basic-element

In recognition activities, some basic-elements are particular to certain matters, for example:

$$B=\begin{bmatrix} \text{mole}, & \text{person who has it}, & \text{A} \\ & \text{location}, & \text{central left buttock} \\ & \text{size}, & \text{pea-sized} \end{bmatrix}$$

This kind of mole is particular to A, so it's the optimal basic-element to recognize A. These basic-elements are called special basic-elements.

The basic-element B_s constituted by the special part O_s of matter O and their peculiar characteristic element is called the special basic-element of matter O, denoted by

$$B_s=\begin{bmatrix} O_s, & c_{s1}, & v_{s1} \\ & c_{s2}, & v_{s2} \\ & \vdots & \vdots \\ & c_{sp}, & v_{sp} \end{bmatrix},$$

If the special parts are multiple, i.e. $\{O_{si}\}$, $i=1,2,...,q$, there are q special basic-elements:

$$B_{si}=\begin{bmatrix} O_{si}, & c_{s1}, & v_{s1} \\ & c_{si2}, & v_{si2} \\ & \vdots & \vdots \\ & c_{sip_i}, & v_{sip_i} \end{bmatrix},\ (i=1,2,..,q)$$

As to the basic-element with matter or class matter as its object, those other than the special basic-element or the key basic-element are collectively called the general basic-elements.

(4) Relativity degree of basic-element and class basic-element

Given class basic-element $\{B\}=\{(\{O\},\ c,\ v)\}$, $v\in V_0$, $B_1=(O_1,\ c,\ v_1)$, with V_0 as positive field, we make dependent function $k(v)$, and call $k(v_1)$ relativity degree between B_1 and class basic-element $\{B\}$, denoted as $k_{\{B\}}(B_1)$.

(5) Truthfulness/falseness and its calculation method

In recognition activities, people collect various types of information, some of which are true, some are false, and some are half a truth. Therefore, the truthfulness/falseness of information must be judged first. The truthfulness/falseness of information can be judged by many methods, and the functions to judge truthfulness/falseness can be divided into three types:

a) Characteristic function

$$\alpha(B) = \begin{cases} 1, & B \text{ is true} \\ 0, & B \text{ is false} \end{cases}$$

b) Membership function

$$\alpha(B) \in [0,1]$$

c) Dependent function

$$\alpha(B) \in (-\infty, +\infty)$$

Truthfulness/falseness of information can be judged by three approaches as follows: (1) by commonsense knowledge; (2) by professional knowledge; (3) by new information and new knowledge after transformation.

Because of limited knowledge capacity of human beings, recognition of existing conditions is limited to a certain extent, and when a contradictory problem cannot be solved i.e. the object cannot be recognized, we can extend the goal and condition, acquire new changed information by extension transformation, and then judge the existing information by common sense or professional knowledge.

3. General steps of extension recognition methods

The extension recognition method is pertinent only to the problems that cannot be recognized by general recognition methods, with recognizability denoted as $\beta < 0$. To recognize that object *O* belongs to class *A*, it's recognized by generally adopting key basic-element; to judge whether *O* is another thing O_*, it's judged by adopting special basic-elements. The process is as follows:

(1) Use basic-elements to express class *A*'s key basic-elements (or object O_*'s special basic-elements) B_{*0i} and object O's corresponding key basic-elements (or special basic-elements) B_{0i};

(2) If it cannot be recognized by such information, extensible analysis or conjugate analysis should be conducted to obtain B_{*i} and B_i;

(3) For B_{*i}, establish dependent function $k_{B_{*i}}(x_i)$ and corresponding extension set of basic-elements $\tilde{E}_{*i}$, and

calculate the relativity degree between B_i and B_{*i}, denoted as $k_{B_{*i}}(B_i)$;

(4) Calculate the relativity degree $k = \overset{n}{\underset{1=1}{\wedge}} k_{B_{*i}}(B_i)$ of O about A;

(5) Make transformation T_i, to obtain basic-element $T_i B_i = B_i'$ after transformation;

(6) Calculate the relativity degree $k_{B_{*i}}\left(B_i'\right)$, $(i = 1, 2, ..., n)$ of B_i' about B_{*i};

(7) Judge the truthfulness/falseness $\alpha\left(B_i'\right)$ of information B_i' after transformation;

(8) Calculate the recognizability after transformation

$$\beta_{B_{*i}}\left(B_i'\right) = \alpha\left(B_i'\right) \bullet k_{B_{*i}}\left(B_i'\right),$$

$$\beta(T) = \overset{m}{\underset{i=1}{\wedge}} \beta_{B_{*i}}\left(B_i'\right)$$

(9) Judge does the key basic-element B_{i_0}' with recognizability of $\beta(T)$ after transformation belongs to which field of the extension set $\tilde{E}_{*i_0}$. If B_{i_0}' belongs to positive extensible fields, i.e. $\beta < 0$, $\beta(T) > 0$ is met, it indicates that B_{i_0} is transformed from not belonging to B_{*i} (unrecognizable) to belonging to B_{*i} through transformation T. Correspondingly, O is transformed from being unrecognizable to belonging to A.

There are also numerous practical problems that require the judgment whether object O is O_* or not. For example, whether A who stays in a certain hotel is the disguised criminal suspect B. We can establish the special basic-element of B and the corresponding special basic-element of A by the method similar to the above one, and repeat the above process to judge whether A is B or not.

In practical problems, to recognize whether certain object O is O_* or not, sometimes we first use key characteristics to recognize whether O_* belongs to certain object class $\{O\}$, and then use special basic-elements to recognize whether it's O or not. For example, when recognizing whether A is B or not in the above case, we can first use key characteristics to judge whether it belongs to the criminal suspect set, and then use special characteristics to judge whether it's B.

The above steps can be expressed as block diagram 3.4.

We have introduced the recognition method by key basic-elements and special basic-elements, and in case these two types of basic-elements cannot be determined, but only a general basic-element is available, preliminary recognition can be conducted by setting weight coefficients and determining the comprehensive recognizability.

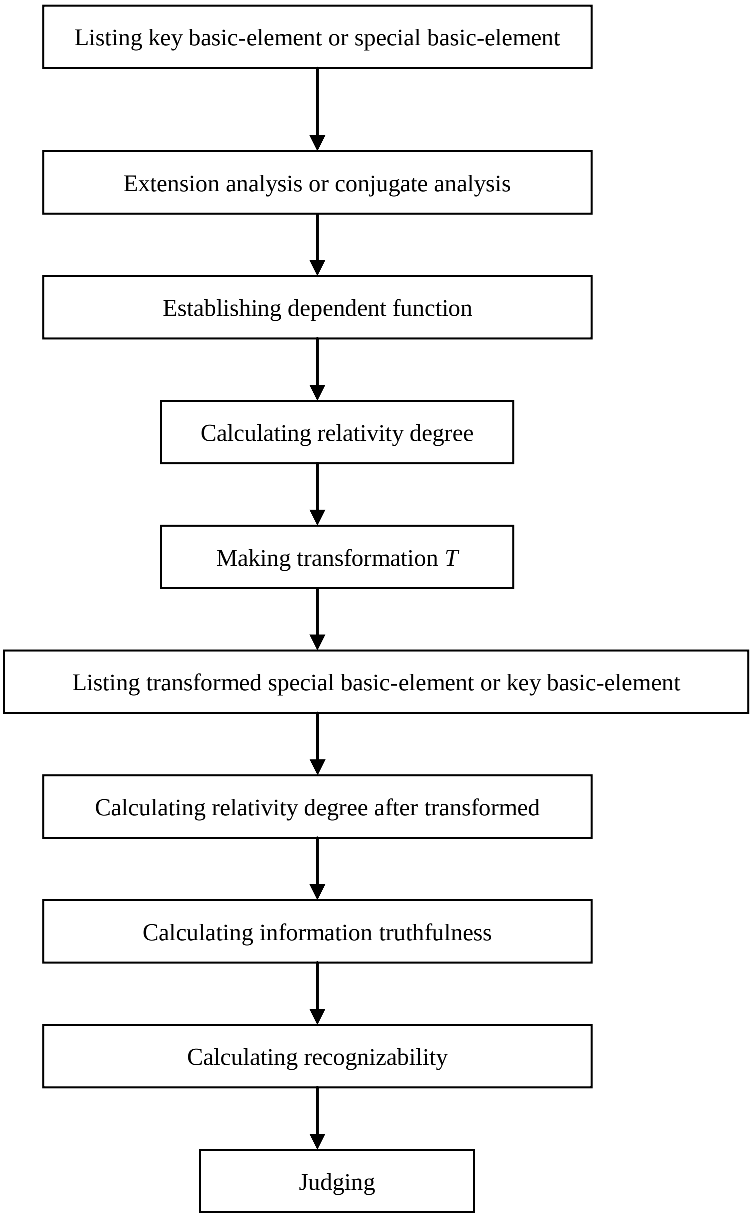


Figure 3.4 General Steps of Extension Recognition Method

3.5 Superiority Evaluation Method

Superiority evaluation method is the basic method to evaluate the superiority of an object, including matter/affair, strategy and method, etc. in Extenics.

3.5.1 Basic Concept

(1) Measuring Indicator

In order to evaluate the superiority of an object, the scale index must be specified first. Superiority is subject to specific standard. An object may be advantageous subject to certain scale indexes, but disadvantageous subject to other scale indexes. Therefore, the evaluation of an object must reflect the degree of its advantage and disadvantage and their possible changes. This requires us to prepare the evaluation standard that complies with the technical requirements, economic requirements and social requirements according to the need of the actual problem, and determine the measuring indicator $MI=\{MI_1,\ \ MI_2,\ \ \cdots,\ \ MI_n\}$, wherein, $MI_i=(c_i,\ \ V_i)$ is characteristic element, c_i is evaluation characteristic, V_i is quantified measure domains $(i=1,\ 2,\ \cdots,\ n)$.

(2) Dependent degree

As to certain evaluation object *Z*, if the indicator to measure certain superiority (i.e. measuring indicator) is *MI*, the qualified range of values is X_0, the measuring range allowed by measures is *X*, measure domain is *V*, we establish dependent function $K(z)$ to indicate the degree that the object *Z* complies with the requirement, and call $K(z)$ dependent degree of *Z* about *MI*.

(3) Standard dependent degree

Suppose the dependent degree of *Z* about *MI* is $K(z)$, then

$$k_Z=\frac{K(z)}{\max\limits_{x\in V}|K(x)|}$$

is called standard dependent degree of *Z* about *SI*.

(4) Superiority

As to certain evaluation object *Z*, if the measuring indicators set is $MI=\{MI_1, MI_2, \ldots, MI_n\}$, the standard dependent degree of *Z* about MI_i is k_i (i=1, 2,…,n), weight coefficient of MI_i is α_i (α_i indicates the relative importance degree of the measuring indicator MI_i) (i=1, 2,…,n), and $0\le\alpha_i\le1$. Then, there is different superiority in the following different cases:

1) In the practical problem, if it's required that only the comprehensive dependent degree of all measuring indicators be more than 0 can the object *Z* be considered qualified, the definition of superiority is $C(Z)=\sum\limits_{i=1}^{n}\alpha_i k_i$.

2) In the practical problem, if only the dependent degree of certain measuring indicator is more than 0 can the object Z be considered qualified, the definition of superiority is $C(Z)=\overset{n}{\underset{i=1}{\vee}} k_i$.

3) In the practical problem, if it's required that only the dependent degree of all measuring indicators be more than 0 can the object Z be considered qualified, the definition of superiority is $C(Z)=\overset{n}{\underset{i=1}{\wedge}} k_i$.

4) In the practical problem, if it's required that the dependent degree of a certain measuring indicator must be more than a certain threshold $\lambda\,(\lambda>0)$, otherwise the object cannot be adopted, this measuring indicator is referred to as the "indispensible index", now we should first evaluate the evaluation objects by this indicator, and then calculate the superiority of all the objects that met the indicator by adopting one of the above three kinds of superiority.

3.5.2 Basic Steps of Superiority Evaluation Method

The basic flow of superiority evaluation method is shown as Figure 3.5:

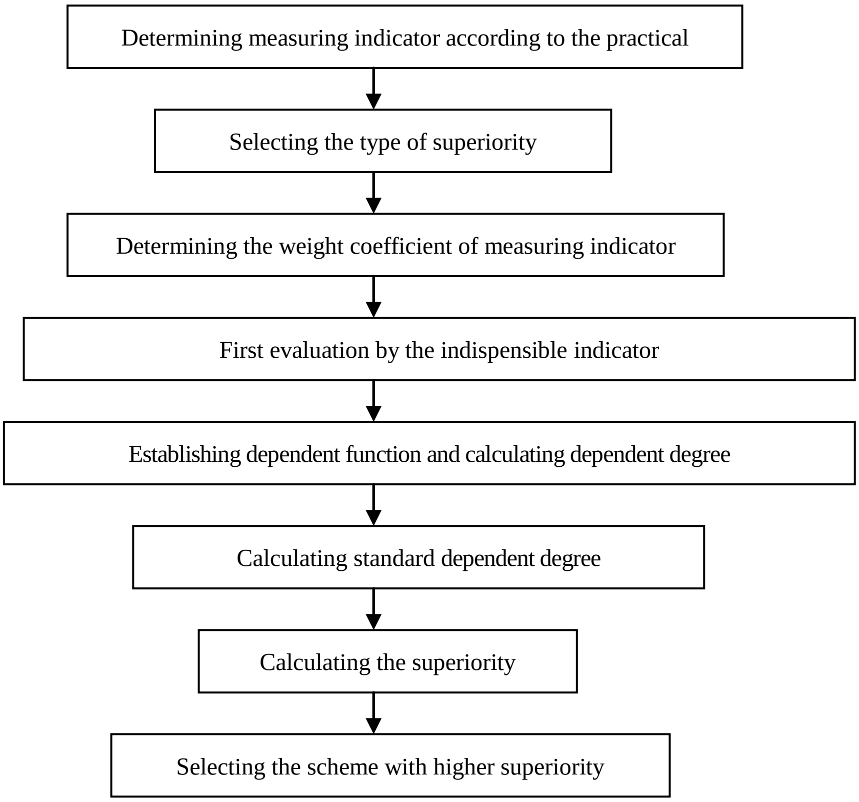


Figure 3.5 Basic Flow of Superiority Evaluation Method

1. Determination of Measuring Indicator (*MI*)

The selection of a measuring indicator is a critical problem, and attention must be paid to the following principles:

1) Purposiveness of evaluation. First, selection of the measuring indicator should be embarked from the purpose of the evaluation. For different types of planning, different measuring indicators should be selected for the evaluation of its creative idea or scheme, for example, the measuring indicators for product design scheme, production scheme, planning idea, marketing scheme, etc. should be different.

2) All-sidedness of evaluation. Superiority evaluation method is a kind of all-sided evaluation. To ensure this, the selected measuring indicator must be representative. The indicator that is the most representative and plays an important role in the realization of the purpose should be selected subject to the technical, economic and social requirements.

3) Feasibility of evaluation. The selected measuring indicator should be not only representative, but also applicable for evaluation. The data on measuring indicator should be easily acquired, true, reliable, and with high quality.

4) Stability of evaluation. The selected measuring indicator should be of regular changes. The indicators that are significantly influenced by accidental factors and will greatly fluctuate should not be selected.

For determination of value range V_i about every measuring indicator MI_i, attention should be paid to the following points:

① It should refer to the actual situation of social and economic phenomena, on the basic of the information of spatial range and history that are related to the evaluation object.

② Attention should be paid to the trend of development and change of social and economic phenomena, and the estimated numeric values of the changes should be used as a reference when determining the value range.

③ Determination of the value range should play a certain role of adjustment and administration, for which, the planned values and schemed values in the social and economic administration of the country (region and department) and other standard data can be considered to be used as the boundary of value range.

2. Determination of weight coefficient

The scale indexes $MI_1,\ MI_2,\ \cdots,\ MI_n$ used to evaluate the superiority of an object $Z_j\ (j=1,\ 2,\ \cdots,\ m)$ are different in terms of weight, and the degree of importance of every measuring indicator is represented by a weight coefficient. The indispensible indicator is indicated by indicator Λ, while the other measuring indicators are given the value between [0, 1] according to their degree of importance. Weight coefficient is denoted by

$$\alpha = (\alpha_1,\ \ \alpha_2,\ \ \cdots,\ \ \alpha_n)$$

wherein, if $\alpha_{i_0} = \Lambda$, then $\sum_{\substack{k=1\\k\neq i_0}}^{n} \alpha_k = \mathbf{1}$.

The size of a weight coefficient is critical for the degree of superiority, and the different weight coefficients will lead to different conclusions, causing changes of superiority sequence of the evaluation objects. However, because the weight coefficient is usually determined artificially, they are usually arbitrary and will influence the truthfulness and reliability of the evaluation. In order to determine weight coefficients as reasonably as possible, we can determine the relative importance sequence between measuring indicators by hierarchy analysis method, so as to determine the weight coefficients.

3. First evaluation

After the weight coefficients of measuring indicators are determined, first sift the evaluation objects by the indispensible indicator to weed the objects that do not meet the indicator, and then conduct the following steps for the objects that meet the indispensible indicator Λ. (Suppose all $Z_1, Z_2, \cdots, Z_m$ meet the indispensible indicator.)

4. Establishment of dependent function and calculation of dependent degree

Suppose measuring indicators set $MI = \{MI_1,\ MI_2,\ \cdots,\ MI_n\}$, $MI_i = (c_i,\ V_i)$, $(i = 1,\ 2,\ \cdots,\ n)$, and weight coefficient distribution is

$$\alpha = (\alpha_1,\ \alpha_2,\ \cdots,\ \alpha_n)$$

According to the requirements of every measuring indicator, establish dependent functions $K_1(x_1), K_2(x_2), \cdots, K_n(x_n)$.

① If V_i is a finite interval X_{0i} or infinite interval, we take the simple dependent function $K_i(x_i)$;

② If V_i is a set of some discrete data, such as SI_i that indicate the product quality rating, and V_i ={level A, level B, level C}, then we take

$$K_i(x_i) = \begin{cases} a, & x_i = \text{level A} \\ b, & x_i = \text{level B} \\ c, & x_i = \text{level C} \end{cases}$$

The values of *a*, *b*, *c* can be obtained by the comments of experts or scores in historical data.

For example, if we required that the product quality rating reached level A for meeting the requirements, and value of 1, level B for critical state, level C for not meet the requirements, and value of-1, then we take

$$K_i(x_i) = \begin{cases} 1, & x_i = \text{level A} \\ 0, & x_i = \text{level B} \\ -1, & x_i = \text{level C} \end{cases}$$

③ If V_i is described by nested intervals without a common endpoint constituted by X_{0i} and X_i ($X_{0i} \subset X_i$), and the optimal point is on point x_0, we take

$$K_i(x_i) = \frac{\rho(x_i, x_0, X_{0i})}{D(x_i, X_{0i}, X_i)}$$

(Other cases are omitted).

The dependent function value of object Z_j about each measuring indicator MI_i is denoted by $K_i(Z_j)$ for easy writing, and then the dependent degree of every object $Z_1, Z_2, \cdots, Z_m$, about MI_i is

$$K_i = (K_i(Z_1),\ K_i(Z_2),\ \cdots,\ K_i(Z_m)),\quad (i = 1,\ 2,\ \cdots,\ n)$$

The above dependent degree is standardized as:

$$k_{ij} = \frac{K_i(Z_j)}{\max\limits_{q\in\{1,2,\cdots,m\}} |K_i(Z_q)|} \quad ,(i=1,\ 2,\ \cdots,\ n;\ j=1,\ 2,\ \cdots,\ m)$$

And then the standard dependent degree of every object $Z_1, Z_2, \cdots, Z_m$ about MI_i is

$$k_i = (k_{i1},\quad k_{i2},\quad \cdots,\quad k_{im}) \quad , \quad (i=1,\ 2,\ \cdots,\ n)$$

5. Calculation of superiority

The standard dependent degree of object Z_j about every measuring indicator $MI_1,\quad MI_2,\quad \cdots,\quad MI_n$ is

$$K(Z_j) = \begin{bmatrix} k_{1j} \\ k_{2j} \\ \cdots \\ k_{nj} \end{bmatrix} \quad ,(j=1,\ 2,\ \cdots,\ m)$$

According to different requirements of the practical problem, the superiority of object Z_j may be in three cases:

(1) $C(Z_j) = \alpha K(Z_j) = (\alpha_1,\quad \alpha_2,\quad \cdots,\quad \alpha_n) \begin{bmatrix} k_{1j} \\ k_{2j} \\ \cdots \\ k_{nj} \end{bmatrix} = \sum\limits_{i=1}^{n} \alpha_i k_{ij} \ ,\quad j=1,\ 2,\ \cdots,\ m$;

(2) $C(Z_j) = \mathop{\vee}\limits_{i=1}^{n} k_{ij},\ j=1,2,\cdots,m$

(3) $C(Z_j) = \mathop{\wedge}\limits_{i=1}^{n} k_{ij},\ j=1,2,\cdots,m$

Comparison of superiority of Z_j : if $C(Z_0) = \max\limits_{j\in\{1,2,\cdots,m\}} \{C(Z_j)\}$, then object Z_0 is preferred.

The evaluation of the (1) kind of superiority can be conducted according to Table 3.2. The evaluation of the (2) and (3) kinds of superiority can be conducted according to Table 3.3. The size of the superiority indicates the degree of superiority of the object.

Table 3.2 Superiority Evaluation of (1) Kind of Superiority

Measuring Indicator	Weight Coefficient	Dependent Degree				Standard Dependent Degree		
		Object Z_1	Object Z_2	…	Object Z_m	Object Z_1	…	Object Z_m
MI_1	α_1	$K_1(Z_1)$	$K_1(Z_2)$	…	$K_1(Z_m)$	k_{11}	…	k_{1m}
MI_2	α_2	$K_2(Z_1)$	$K_2(Z_2)$	…	$K_2(Z_m)$	k_{21}	…	k_{2m}
…	…	…	…	…	…	…	…	…
MI_n	α_n	$K_n(Z_1)$	$K_n(Z_2)$	…	$K_n(Z_m)$	k_{n1}	…	k_{nm}

Superiority			$\sum_{i=1}^{n}\alpha_i k_{i1}$ $\cdots$ $\sum_{i=1}^{n}\alpha_i k_{im}$

Table 3.3 Superiority Evaluation of (2) and (3) Kinds of Superiority

Measuring Indicator	Dependent Degree				Standard Dependent Degree		
	Object Z_1	Object Z_2	…	Object Z_m	Object Z_1	…	Object Z_m
MI_1 MI_2 $\cdots$ MI_n	$K_1(Z_1)$ $K_2(Z_1)$ $\cdots$ $K_n(Z_1)$	$K_1(Z_2)$ $K_2(Z_2)$ $\cdots$ $K_n(Z_2)$	$\cdots$ $\cdots$ $\cdots$ $\cdots$	$K_1(Z_m)$ $K_2(Z_m)$ $\cdots$ $K_n(Z_m)$	k_{11} k_{21} $\cdots$ k_{n1}	$\cdots$ $\cdots$ $\cdots$ $\cdots$	k_{1m} k_{2m} $\cdots$ k_{nm}
Min. Superiority					$\overset{n}{\underset{i=1}{\wedge}} k_{i1}$	$\cdots$	$\overset{n}{\underset{i=1}{\wedge}} k_{im}$
Max. Superiority					$\overset{n}{\underset{i=1}{\vee}} k_{i1}$	$\cdots$	$\overset{n}{\underset{i=1}{\vee}} k_{im}$

Note: during the process of solving practical problems, some indicators are indispensible, and if these indicators are not met, any other indicator, even the best one, cannot be used. For example, when designing a building, as for the selection of materials and configuration of equipment, etc., the indicators about safety coefficients are indispensible. Any material, equipment and scheme that does not meet safety requirement cannot be used.

When evaluating one object, we should consider both its advantageous and disadvantageous aspects. For example, when an enterprise is manufacturing certain product, although the profit is desirable, the waste gas extremely pollutes the environment, while another product is less profit but has no public hazard. As to the selection of the product, we must conduct a comprehensive evaluation by considering both advantageous and disadvantageous aspects, and then obtain the appropriate sifting scheme. In addition, at evaluation, the dynamism and changeability, as well as latent advantage and disadvantage, should be usually taken into consideration.

3.5.3 Multilevel Superiority Evaluation Method

There are many measuring indicators involved by the evaluation of complicated objects, while each measuring indicator should be given a certain weight, therefore, in case of multiple measuring indicators, there will be the following problems:

(1) Weights can be hardly distributed as appropriate. Because distribution of weights mainly depends on the subjective judgment of people, when there are too many indicators, correct judgment can be hardly made. In addition, because measuring indicators may be hierarchical, even if hierarchy analysis method, etc. is applied, it’s difficult to distribute correctly the weights of measuring indicators at different hierarchies.

(2) Meaningful evaluation results cannot be obtained. Because each weight usually has the property of normalization, when there are multiple measuring indicators, the weight must be very small, thus the position of each measuring indicator in the whole can be hardly reflected as it is.

Given this, this kind of problem should be solved by adopting multilevel (or hierarchical) superiority evaluations. By utilizing the multilevel superiority evaluation method, the evaluation object is comprehensively evaluated by first dividing the measuring indicators into levels, on the basis of the superiority evaluation method introduced above, and then giving weight to each measuring indicator on each level.

The steps of multilevel evaluation method are as follows:

1. Establishment of measuring indicators system first according to the practical problem

$$MI\left[\begin{array}{l} MI_1\left[\begin{array}{l} MI_{11}\left[\vdots\right. \\ MI_{12}\left[\vdots\right. \\ \vdots \\ MI_{1m_1}\left[\vdots\right. \end{array}\right. \\ MI_2\left[\begin{array}{l} MI_{21}\left[\vdots\right. \\ MI_{22}\left[\vdots\right. \\ \vdots \\ MI_{2m_2}\left[\vdots\right. \end{array}\right. \\ \vdots \\ MI_n\left[\begin{array}{l} MI_{n1}\left[\vdots\right. \\ MI_{n2}\left[\vdots\right. \\ \vdots \\ MI_{nm_n}\left[\vdots\right. \end{array}\right. \end{array}\right.$$

Wherein, $MI=\{MI_1,\ \ MI_2,\ \ \cdots,\ \ MI_n\}$ are level 1 measuring indicators;

$MI_i=\{MI_{i1},\ \ MI_{i2},\ \ \cdots,\ \ MI_{im_i}\}, i=1,2,\cdots,n$ are level 2 measuring indicators, and so on.

2. Determination of weight coefficient

Determine weight coefficients for measuring indicators at each level. The indispensible indicator can be expressed by indicator Λ, while other measuring indicators can be given the value between [0,1] according to their different degrees of importance.

Weight coefficients of level 1 measuring indicators are denoted by

$$A=(\alpha_1,\ \ \alpha_2,\ \ \cdots,\ \ \alpha_n)$$

wherein, if $\alpha_{i_0}=\Lambda$, then $\sum\limits_{\substack{k=1\\k\neq i_0}}^{n}\alpha_k=1$.

Weight coefficients of level 2 measuring indicators are denoted by

$$A_i=(\alpha_{i1},\ \ \alpha_{i2},\ \ \cdots,\ \ \alpha_{im_i}), i=1,2,\cdots,n$$

wherein, if $\alpha_{ij_0}=\Lambda$, then $\sum\limits_{\substack{k=1\\k\neq j_0}}^{m_i}\alpha_{ik}=1,\ \ i=1,2,\cdots,n$.

3. First evaluation

After the weight coefficient of every measuring indicator is determined, first sift the evaluation objects by the indispensible indicator to weed the objects that do not meet the indicator, and then conduct the following steps for the objects that meet the indispensible indicator Λ .

4. Establishment of dependent function and calculation of dependent degree

First establish dependent function of the measuring indicator at the lowest level. As to level *j*, suppose there are *s* measuring indicators, and establish dependent function according to the method given in 3.5.2(4), subject to the requirement of each measuring indicator, to calculate the superiority of each indicator at each level. And then calculate the superiority of the upper levels by order until the top level is calculated, now the comprehensive superiority is obtained.

3.5.4 Problems Must Be Noticed During Evaluation by the Superiority Evaluation Method

The superiority evaluation method is a kind of method frequently used in evaluations at present, which uses dependent functions to determine the qualified degree of the evaluation object (basic-element) about certain measuring indicators. Pertinent to the actual requirement of measuring indicators, we may select simple dependent functions, dependent functions with optimum point at the midpoint of positive field intervals, dependent functions with optimum points not on the midpoint of positive field intervals, discrete-type dependent functions, and interval-type dependent functions, etc.

In the case of multiple measuring indicators, the comprehensive superiority of each evaluation object should be calculated according to the requirement of the practical problem, to determine the superiority or level of the evaluation objects, in which, there are also many methods to determine the weight coefficients, which should be selected as appropriate according to the specific problem.

The following problems should be noticed when applying the superiority evaluation method:

1) Dependent function should be selected as appropriate; otherwise the evaluation result will be influenced.

2) In case of the problem that has multiple systems and multiple measuring indicators and has to be comprehensively evaluated, we can respectively discuss each system by the above methods and then conduct comprehensive analysis, or construct different extension transformations for each system by fully utilizing the extensibility and changeability of basic-elements. This practice of comprehensive consideration is more all-sided, but can be hardly adopted in case of less correlation of every system because of its higher requirement for operation environment and more difficulty for running inspection.

3) In case the values range of the evaluation object about certain measuring indicators is nested interval, some nested intervals are definite, while some are dynamic and changing. Dynamic evaluation that takes into consideration the changeability of interval endpoints and hierarchical changes in the interval will help the study of this kind of problems.

3.6 Extension Thinking Mode

Thinking is the active, general and indirect reflection process of the real world by the human brain. It's conducted through analysis and synthesis of perceptual materials by discarding the dross and selecting the essential, eliminating the false and retaining the true, proceeding from one to the other and from the outside to the inside, on the basis of social practice.

Because of the variability, innovativeness and competitiveness of market economy, people must, at any moment, guard against and break through the inherent thinking stereotype and models in their brain, overcome the habituation and restriction of empirical thinking patterns, and pursue creative thinking.

Creative thinking is the thinking conducted in non-habitual modes, i.e. "thinking of the never thought and doing of the never done". Its most material difference from regular thinking lies in that regular thinking is usually logical thinking and empirical thinking, while creative thinking, is relative but not absolute. It's impossible for thinking itself to be like a heavenly steed soaring across the sky to and fro all alone, as restricted by numerous factors, such as the objective environment, educational background, and physiological condition, etc., which restricts the transcendence and creation levels of the specific person. Nevertheless, one of the superiorities of human beings is reflected in that a man can be aware of this kind of restriction and continuously break these restrictions, to realize new thinking full of originality. The whole progressive history of human beings is a history of continuous innovations from impossible to possible and from possible to realization.

Creative thinking usually means theoretical breakthroughs and practical success. Therefore, for hundreds and thousands of years, people in China and abroad, ancient and modern, have been endeavored to summarize the laws of creative thinking and explore the secrets therein, achieved extremely abundant accomplishments. But it's regretful that, until now, it can be hardly said that the study results of creative thinking is a science with explicit concepts and complete systems, and both relevant theoretical study and practical accomplishments have drawbacks that can be hardly overcome.

From the viewpoint of Extenics, anything has extendibility. The extendibility and conjugacy are the basis for innovation. It's extremely appropriate to apply the thinking and methods of extension analysis, conjugate analysis, extension transformation and extension set in human thinking fields. It solved the problems of "how to innovate thinking", "from where to innovate" and "how to evaluate the result of creative thinking", etc. It's on this basis that Extenics proposed four creative thinking modes: Rhombus thinking mode, reverse thinking mode, conjugate thinking mode and conductive thinking mode.

3.6.1 Rhombus Thinking Mode

The rhombus thinking mode is a thinking mode beginning with divergence and ending with convergence, so it includes two steps of divergent thinking and convergent thinking.

Many activities that people engaged in can be described with the concept of basic-element. Multiple basic-elements can be extended from certain basic-element by employing extensible analysis methods along different paths, to obtain a lot of information, providing a well-stocked bank of resources for analyzing and solving problems, which is the divergent process. Divergent thinking is the first step of creative thinking, mainly aiming for quantity and thinking widening first. On this basis, according to the limitation of objective conditions and different requirements for solving different problems, the large amount of basic-elements obtained from divergent processes can be evaluated regarding their feasibility, superiority/inferiority, truthfulness/falseness and compatibility, to sift a small quantity of qualified basic-elements, which is referred to convergent processes. As the second step of creative thinking, convergent thinking mainly aims for focusing the widened thinking in optimal directions. Finally, extension transformation or comprehensive handling can be made to the selected basic-elements, to obtain unusual new views, new ideas and schemes. Such process is the one-step rhombus thinking process. Sometimes we can adopt the multiple cycling of "divergence – convergence – re-divergence – re-convergence" to form multi-step rhombus thinking. The one-step thinking mode expressed by basic-elements is shown as Figure 3.6:

$$B_1=(O_1,\ c_1,\ v_1)$$

$$B=(O,\ c,\ v) \qquad B_2=(O_2,\ c_2,\ v_2) \qquad B_1'=(O_1',\ c_1',\ v_1')$$

$$\cdots \qquad \cdots \qquad \text{(where } n>m\text{)}$$

$$B_n=(O_n,\ c_n,\ v_n) \qquad B_m'=(O_m',\ c_m',\ v_m')$$

Figure 3.6 One-Step Rhombus Thinking Mode

In the above mode, the divergent process is B—$|\{B_1,\ B_2,\ \ldots,\ B_n\}$, which is conducted on the basis of basic-element's extendibility or matter-element's conjugacy, by using the extensible analysis method, conjugate analysis method and extension transformation method, while the convergent process, i.e. $\{B_1,\ B_2,\ \ldots,\ B_n\}|$—$\{B'_1,\ B'_2,\ \ldots,\ B'_m\}$ can be sifted and evaluated by adopting appropriate evaluation methods, such as the superiority evaluation method introduced in 3.6, to obtain the expected basic-elements.

[Example 3.25] Rhombus thinking mode in series products development of washing machine of certain brand

An enterprise manufacturing washing machines has been started not early, but its product development is particularly featured comparing to many manufacturing plants in the same industry, especially the rhombus thinking mode in its product development, which is not only eye-catching in the whole industry of washing machines, but also significant for reference by the whole industrial field.

By careful research on the product innovation process of the washing machine, we can discover its rhombus thinking tracks:

$$M=\begin{bmatrix}\text{washing machine } O, & \text{purpose}, & \text{clothes washing}\\ & \text{washing loads}, & 5kg\\ & \text{application field}, & \text{household}\end{bmatrix}=\begin{bmatrix}M_1\\ M_2\\ M_3\end{bmatrix}$$

$$M_1-|\begin{cases}M_{11}=(\text{washing machine } O_1,\ \ \text{purpose},\ \ \text{sweet potato washing})\\ M_{12}=(\text{washing machine } O_2,\ \ \text{purpose},\ \ \text{vegetable shortening})\\ M_{13}=(\text{washing machine } O_3,\ \ \text{purpose},\ \ \text{potato unpeeling})\end{cases}$$

$$M_2-|\begin{cases}M_{21}=(\text{washing machine } O_4,\ \ \text{washing loads},\ \ 3kg)\\ M_{22}=(\text{washing machine } O_5,\ \ \text{washing loads},\ \ 1.5kg)\end{cases}$$

$$M_3-|\begin{cases}M_{31}=(\text{washing machine } O_6,\ \ \text{application field},\ \ \text{barrack})\\ M_{32}=(\text{washing machine } O_7,\ \ \text{application field},\ \ \text{industry})\\ M_{33}=(\text{washing machine } O_7,\ \ \text{application field},\ \ \text{catering industry})\end{cases}$$

The schemes obtained from divergent analysis cannot be totally applied, but should be evaluated and sifted according to the measuring indexes in practical application, to obtain the schemes with higher superiority. For example, the following can be obtained by employing superiority evaluation methods:

$$M_{01}=\begin{bmatrix}\text{washing machine } O_1, & \text{purpose}, & \text{sweet potato washing}\\ & \text{washing loads}, & 5kg\\ & \text{application field}, & \text{household}\end{bmatrix}$$

$$M_{02}=\begin{bmatrix}\text{washing machine } O_2, & \text{purpose}, & \text{vegetable shortening}\\ & \text{washing loads}, & 3kg\\ & \text{application field}, & \text{industry}\end{bmatrix}$$

$$M_{03}=\begin{bmatrix}\text{washing machine } O_3, & \text{purpose}, & \text{potato unpeeling}\\ & \text{washing loads}, & 5kg\\ & \text{application field}, & \text{catering industry}\end{bmatrix}$$

$$M_{04}=\begin{bmatrix}\text{washing machine } O_4, & \text{purpose}, & \text{clothes washing}\\ & \text{washing loads}, & 1.5kg\\ & \text{application field}, & \text{household}\end{bmatrix}$$

$$M_{05}=\begin{bmatrix}\text{washing machine } O_5, & \text{purpose}, & \text{clothes washing}\\ & \text{washing loads}, & 5kg\\ & \text{application field}, & \text{barrack}\end{bmatrix}$$

By the above scheme, the following washing machines can be developed:

sweet potato washing” machine，“ vegetable shortening” machine，“ potato unpeeling” machine，
child prodigy” washing machine，“ camoufluge colored” washing machine

It can be seen that the key to product development is continuous creation of thinking, for product design according to customer requirement by weeding out the old and bringing forth the new, and even for customization.

Multi-step rhombus thinking mode is shown as Figure 3.7:

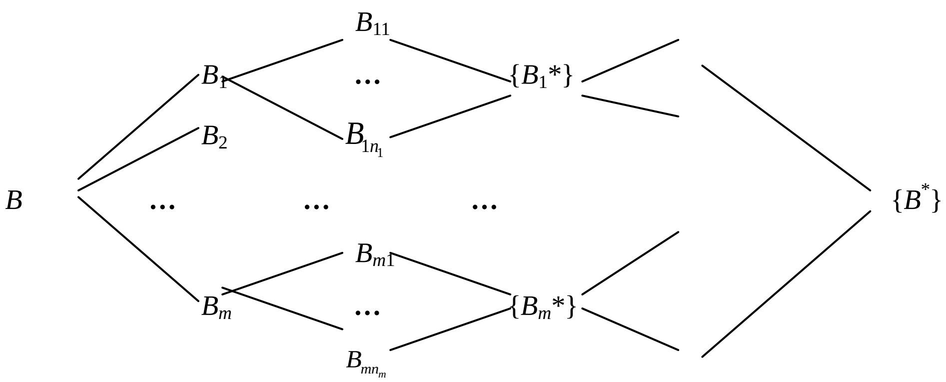


Figure 3.7 Multi-Step Rhombus Thinking Mode

3.6.2 Reversed Thinking Mode

Reversed thinking is the mode to think problems consciously from the direction contrary to regular thinking, as a thinking that breaks through regularity and looks for variation, i.e. “thinking from the reverse side” and “doing the opposite”. It changes people’s habit to explore problems from the front and actively breaks through the unidirectivity, oneness, habituation and logicality of the regular thinking, therefore, although it does not comply with the regular logic, but can produce unusual thoughts and marvelous new conceptions and ideas. More significant innovation can usually be obtained by applying the reversed thinking.

From the angle of creatology, common revered thinking patterns include principle reverse, attribute reverse, directional reverse and methodological reverse. As a kind of irregular creative thinking mode, with significant difficulty for its formalized study, reversed thinking is more difficult for people to master. However, several modes of reversed thinking can be given by employing the formalized method in Extenics. Next, we will provide the four types of thinking modes that are commonly used for formalized description of reversed thinking, on the basis of basic-element, reverse transformation and implication relation, etc. in Extenics.

1. Reversed thinking mode by utilizing inverse matter-element and negative matter-element

(1) Inverse matter-elements

The so-called inverse matter-elements refer to the matter-elements whose measures of their matters about certain characteristic are antithetical to each other. Inverse matter-elements can be expressed by formalization as:

Suppose matter-elements $M_1=(O_1,\ \ c,\ \ v_1)$, $M_2=(O_2,\ \ c,\ \ v_2)$, if v_1 and v_2 are measures antithetic to each other, we call matter-elements M_1 and M_2 are inverse matter-elements to each other about characteristic *c*, denoted as $M_1=\underline{M}_2$ or $M_2=\underline{M}_1$.

For example, matter-element $M_1=(\text{acid } A,\ \ \text{PH},\ \ a)$ and matter-element $M_2=(\text{alkali } B,\ \ \text{PH},\ \ -a)$ are inverse matter-elements.

(2) Non-matter-elements

The so-called negative matter-elements refer to the matter-elements whose measures of their matters about certain characteristic are negative to each other. Negative matter-elements can be expressed by formalization as:

Suppose matter-elements $M_1=(O_1,\ \ c,\ \ v_1)$, $M_2=(O_2,\ \ c,\ \ v_2)$, if v_1 and v_2 are non-measures to each other, we call matter-elements M_1 and M_2 are non-matter-elements to each other about characteristic *c*, denoted as $M_1=\bar{M}_2$ or $M_2=\bar{M}_1$.

For example, matter-element $M_1=(A,\ \ \text{location},\ \ \text{east})$ and matter-element $M_2=(A,\ \ \text{location},\ \ \text{west}\vee\text{south}\vee\text{north})$ are non-matter-elements to each other.

Notice: inverse matter-elements differs from negative matter-elements, for example, as to a cube, suppose its 6 faces are respectively A_1, A_2, A_3, A_4, A_5, A_6, if matter-elements

$$M_1=(A_1,\ \ \text{location},\ \ \text{upper part}),\ M_6=(A_6,\ \ \text{location},\ \ \text{lower part}),$$

M_1 and M_6 are inverse matter-elements to each other;

if $M_2 = (A_2,\ \text{location},\ \text{left part})$, $M_4 = (A_4,\ \text{location},\ \text{right part})$, M_2 and M_4 are inverse matter-elements to each other;

if $M_1 = (A_1,\ \text{location},\ \text{upper part})$, $M_i = (A_i,\ \text{location},\ a_i)$, $i = 2,3,4,5,6$,

$a_i =$ {lower part, left part, right part, front part, back part}, M_1 and $\overset{6}{\underset{i=2}{\wedge}} M_i$ are non-matter-elements to each other.

Inverse matter-elements can be matter-elements with the same matter or with different matters. These two kinds of inverse matter-elements can be found abundantly in the real world.

In the process of solving contradictory problems, a certain matter-element is usually a matter-element of regular thinking, and if the solution to the contradictory problem cannot be found by this matter-element, we can try to look for its inverse matter-element or non-matter-element, to consider the solution to the contradictory problem from its inverse or non-matter-element. This thinking mode is a reversed thinking mode by utilizing inverse matter-element or non-matter-element.

For example, a metal ball is rolling down a slope, which is considered normal, because the metal ball has weight. But can you imagine a metal ball rolling up a slope? People never visited S&T exhibit or without certain physical knowledge must consider it's impossible, but it's proved by scientists absolutely possible.

[Example 3.26] When the development of the rocket was nearly successful, the experts came across a bottleneck, i.e. the problem of balance of the rocket at launching could not be solved. Later, someone proposed to attach an object to the rocket tail to solve the problem of balance. However, since the temperature of the rocket tail was very high at launching, experts shifted their attention to looking for "high temperature resistant" attachments. But this kind of material had not been found due to the conditions of that age and experts were at a loss regarding what to do. At that moment a young expert suddenly came up with an idea to look for "high temperature resistant" materials? The goal was rocket balance, but the balance problem would disappear when the rocket's speed reached a certain level. Was it enough if the material could merely ensure the rocket balanced during the initial phase? Since burning-out of this material was not harmful to the rocket, he boldly proposed they attach flammable "wooden" material to the rocket tail. As proved by a test, the bottleneck frustrated the experts for a long time then was easily solved by this cheap and easily found material

This case is a kind of reversed thinking mode to look for the solution to contradictory problems by employing non-matter-elements. Suppose the material to be attached is P, according to the experts' experience and conditions of the rocket tail, the matter-element of regular thinking by the experts is

$$M_1 = \begin{bmatrix} \text{P, function}, & \text{high temperature resistant} \\ \text{purpose}, & \text{for rocket balance} \end{bmatrix}$$

This matter-element's non-matter-element is

$$M_2 = \begin{bmatrix} \text{P, function}, & \text{non high temperature resistant} \\ \text{purpose}, & \text{for rocket balance} \end{bmatrix}$$

It's obvious that matter-element M_1 cannot be realized, but matter-element M_2 has many possibilities. In this case it was such "non-high temperature resistant" materials of wood utilized by the young expert.

2. Reversed thinking mode by utilizing reverse affair-element

The so-called reverse affair-element refers to the affair-element whose action is reverse or whose measure of action about certain characteristic is reverse, expressed by formalization of affair-element as follows:

Suppose affair-elements $A_1=(O_1,\ c,\ v_1)$, $A_2=(O_2,\ c,\ v_2)$, if actions O_1 and O_2 are reverse to each other, or measures v_1 and v_2 are reverse to each other, the affair-elements A_1 and A_2 are called reverse affair-elements about characteristic *c*, denoted as $A_1=A_2^{-1}$ or $A_2=A_1^{-1}$.

In our real life, reverse actions are found abundantly, such as "input" and "output", "borrow" and "lent", "progress" and "regress", and "increase" and "decrease", etc. When solving a contradictory problem, if it cannot be solved by considering from one event, we may consider from its reverse aspect to see if it can be broken through. Such thinking mode is the reversed thinking mode by using the reverse affair-element. For example, the regular thinking of "water flows downwards" cannot be used to solve the problems of "diverting water up to mountains" and "water consumption in highrises", etc., i.e. the reverse problem of "water flows upwards". After the thinking mode was changed, people won't consider that "water flows upwards" is impossible, hence pressure pumps and other equipment were invented, making revolutionary changes in human life.

[Example 3.27] Learning that location A is super-abound with a kind of crystal peach with peel thin as paper and taste sweet as honey, certain fruits dealer established with the local cooperative a supply and sales contract of hundreds of tons. The dealer became aware only before receiving goods that such crystal peaches have vital drawbacks particularly their short shelf life (generally storage of 3 to 5days), particularly inconvenient transport and storage, and being vulnerable to collision and brokerage just because they have thin peel, thick flesh and rich juice. According to the normal sales mode, the series of steps from picking, procurement, casing, transport, wholesale, to retail required at least 10 days. Now the dealer face a dilemma: continuous execution of the contract would undoubtedly lead to the loss of money; termination of the contract would lead to huge amounts of compensation and sweep off its business reputation for many years.

In this case, the goal affair-element is

$$A_g=(\text{sales},\ \ \text{dominating object},\ \ \text{crystal peaches})$$

The original sales mode is

$$A_1=\begin{bmatrix}\text{deliver}, & \text{dominating object}, & \text{buyers}\\ & \text{time}, & 10\text{ days}\end{bmatrix}=\begin{bmatrix}A_{11}\\ A_{12}\end{bmatrix}$$

The condition matter-element is

$$A_l=(\text{crystal peaches},\ \ \text{storage period},\ \ 3\text{—}5\text{ days})$$

It's obvious that the time spent by the original sales mode is far more than the storage period of the crystal peach, and in this case, the goal affair-element can be hardly realized.

A_{11}'s reverse affair-element is

$$A_{11}^{-1}=A_{21}=(\text{invite},\ \ \text{dominating object},\ \ \text{buyers}),$$

and the constituted new sales mode is

$$A_2=\begin{bmatrix}\text{invite}, & \text{dominating object}, & \text{buyers} \\ & \text{time}, & \text{1 day}\end{bmatrix}=\begin{bmatrix}A_{21} \\ A_{22}\end{bmatrix}$$

If A_2 can be realized, the goal can be achieved.

By utilizing such a thinking mode, the dealer started the characteristic tourism project "to tour in Peach Mountain, swim in Peach River, eat Peach fish, and taste Crystal Peach". Not only the brand new mode of indirect sales of crystal peach avoided the original risk but it brought forth handsome profits (i.e. transforming the original "delivery peaches out for sales" to "inviting visitors in to purchase".

[Example 3.28] At the end of the 18th century, Edward Jenner, a famous British doctor, was busy solving a difficulty that existed for thousands of years: variola. After studying on cases one after another, he still could not find a feasible therapy. His thoughts were trapped in the Serbonian bog. At that moment, Doctor Jenner blazed a trail: he stopped his struggle with the problem and diverted the direction of solving the problem – diverted his main efforts from the patients of variola to people not infected with the disease. As a result, it was discovered that the female milkers were not infected with this disease. So he took out a slight quantity of smallpox vaccines from the hands of female milkers and inoculated it into the arm of an 8-year old boy, and it was approved by experiment one month later that Jenner had found the weapon against variola, and consequently eliminated the disease that plagued the western world for thousands of years.

In this case, the goal affair-element $A_g = (\text{cure}, \ \text{dominating object}, \ \text{variola})$, and $A_1 \overline{@}$,

the condition affair-element $A_l = (\text{study}, \ \text{dominating object}, \ \text{variola patients})$.

Their reverse affair-elements respectively are

$$A_g^{-1} = \left[(\text{cure})^{-1}, \ \text{dominating object}, \ \text{variola}\right] \text{—|} A_g' = (\text{prevent}, \ \text{dominating object}, \ \text{variola}), \text{ and } A_g^{-1}@,$$

$$A_l^{-1} = A_l' = (\text{study}, \ \text{dominating object}, \ \text{people not infected with variola})$$

to find the reason for not infected with variola from A_l', i.e. obtain the method to prevent variola.

This reversed thinking mode of using reverse affair-elements is commonly used when solving contradictory problems. For example, in the early stages of invention of tungsten filament bulbs, the bulb was vacuum-pumped. But tungsten filament was easy to become crispy when energized and blackened after a short time. To improve this drawback, Langmuir, the inventor, adopted the above reversed thinking mode to fill the bulb with gas, and consequently invented the gas-filled bulb.

3. Reversed thinking mode by utilizing reverse transformation

Reverse transformation is relative to another transformation. As to certain object Γ, there is transformation T to let $T\Gamma = \Gamma'$, if there is another transformation T' to let $T'\Gamma' = \Gamma$, we call T' reverse transformation of transformation T, denoted as $T' = T^{-1}$, and $TT^{-1} = E$.

The reversed thinking mode by using reverse transformation is: as to certain object Γ, if transformation T cannot be found to let $T\Gamma=\Gamma'$, but the reverse transformation T^{-1} can be found to let $T'\Gamma'=\Gamma$, it can considered that transformation T is realized.

[Example 3.29] In ancient times, there was a king who wanted to test the wisdom of one idea man so he said: "are you able to invite me from my throne to the vermilion steps?" The idea man replied "I can't. But if you are standing on the steps, I am able to invite you back to your throne." After hearing that, the king said: "I don't believe you." and left his throne to stand on the vermilion step. Then the idea man said with a smile "are you not invited to the vermilion step?"

In this case, the method used by the idea man is reverse transformation.

$$M=(\text{king}，\ \text{location}，\ \text{throne})$$

The king wanted the idea man to make transformation T to let $TM=(\text{king}，\ \text{location}，\ \text{vermilion step})=M'$.

It's obvious that other than transformation $T\overline{@}$, the idea man made transformation T^{-1}, to let

$$T^{-1}M'=(\text{king}，\ \text{location}，\ \text{throne})=M$$

Since the king didn't believe the transformation T^{-1} of the idea man could be realized, he left his throne and descended to the vermilion step. But the goal of the idea man was not to realize T^{-1} but T. Through such reverse transformation, the idea man had the king's goal changed, and consequently achieved his own goal.

Such reversed thinking modes use reverse transformation as a method to come up with many good ideas and marvelous strategies.

Since a transformation can be expressed by affair-elements, reverse transformation is a special case of reverse affair-elements. This case can also be analyzed by a reverse thinking mode using reverse affair-elements. Interested readers may want to try it themselves.

4. Reversed thinking mode by utilizing reverse implication

In Extenics, we give the definition of implication relation: if A@, then B@, and we say A implies B, denoted as $A\Rightarrow B$.

The so-called reverse implication is the implication relation by interchanging the locations of A and B in the above implication relation, i.e. if B@, then A@, we say B implies A, denoted as $B\Rightarrow A$.

This implication relation is a reverse implication of the previous implication relation.

[Example 3.30] In 1820, Oersted, a Danish physicist, discovered the magnetic effect of electric currents, i.e. if object A was running through a current, then object A had magnetism, i.e. "$\text{electricity}\Rightarrow\text{magnetism}$". Since then, many scientists began to think this problem: Since electricity could generate magnetism, could magnetism generate electricity? In 1822, 31 year old Faraday started the experiment to transform magnetism to electricity. Through untiring efforts for 10 years, he finally discovered the phenomenon of magnetism generating electricity in 1831, called electromagnetic induction phenomenon, i.e. "$\text{magnetism}\Rightarrow\text{electricity}$". Afterwards, Faraday established the fundamental law of electromagnetism, and disclosed the relation between magnetism and electricity, which became the basis for modern electrotechnics. Faraday also designed the first induction generator in history by using the electromagnetic principle.

Such reversed thinking mode is commonly used by scientists. Many converse theorems and converse propositions were proposed by such thinking modes.

During the process of solving contradictory problems, if it could not be solved by regular implication relations, we may consider whether its reverse implications could be established, if yes, unexpected results would be achieved.

3.6.3 Conjugate Thinking Mode

A study on the structure of matters can help us solve contradictory problems by utilizing every component of the matter. Based on the relevant theories of Extenics, and embarking from matter's materiality, systematicness, dynamism and antithesis, four pairs of antithetical concepts of imaginary and real, soft and hard, latent and apparent, and negative and positive are proposed, for a complete description of the structure and composition of matter and the profound disclosure of the nature of matter's development and change. Any matter has the eight parts of imaginary and real, soft and hard, latent and apparent, and negative and positive, and the conjugate parts of matter can be transformed reciprocally under certain conditions. Through conjugate analysis of matter, we can not only recognize the matter in every way, but also look for the approach to solve the problem by utilizing the reciprocal transformation between conjugate parts, to conduct exploitation and innovation.

Conjugate thinking mode, as a kind of thinking mode particular to Extenics, is based on the matter's conjugate analysis principle and conjugate transformation principle. By applying this kind of thinking mode, we can obtain more overall understanding of matter's structure, analyze its advantages and disadvantages, and pertinently adopt corresponding measures to achieve the predetermined goal according to the reciprocal transformation of conjugate parts under certain conditions. Its basic modes are as follows:

Matter O_m=matter O_m's real part $\oplus$ matter O_m's imaginary part $\oplus$ matter O_m's medium part of imaginary and real

=matter O_m's hard part $\oplus$ matter O_m's soft part $\oplus$ matter O_m' medium part of soft and hard

=matter O_m's apparent part $\oplus$ matter O_m's latent part $\oplus$ matter O_m's medium part of latent and apparent

=matter O_m's positive part $\oplus$ matter O_m's negative part $\oplus$ matter O_m's medium part of negative and positive

expressed by symbols as:

$$
\begin{aligned}
O_m &= \mathrm{re}(O_m) \oplus \mathrm{im}(O_m) \oplus \mathrm{mid}_{\text{im-re}}(O_m) \\
&= \mathrm{hr}(O_m) \oplus \mathrm{sf}(O_m) \oplus \mathrm{mid}_{\text{sf-hr}}(O_m) \\
&= \mathrm{ap}(O_m) \oplus \mathrm{lt}(O_m) \oplus \mathrm{mid}_{\text{lt-ap}}(O_m) \\
&= \mathrm{ps_c}(O_m) \oplus \mathrm{ng_c}(O_m) \oplus \mathrm{mid}_{\text{ng(c)-ps(c)}}(O_m)
\end{aligned}
$$

and expressed as Figure 3.8:

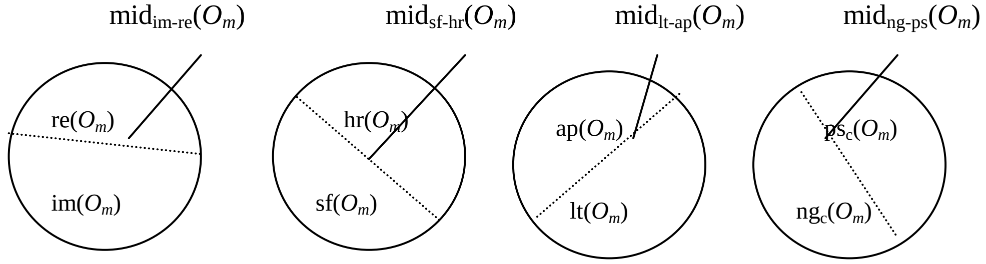


Figure 3.8 Conjugate Thinking Mode

In the process of solving contradictory problems, well application of conjugate thinking mode can realize not only all-sided and correct analysis of our own advantages and disadvantages, but also overall learning about our competitor's situation, to improve our competitiveness.

The content relevant to conjugate analysis and conjugate transformation is not described in detail herein; please refer to the corresponding contents in this book.

3.6.4 Conductive Thinking Mode

In 2.4, we introduced the knowledge relevant to conductive transformation and conductive effect. The so-called conductive transformation is the transformation occurring within an object resulting from certain transformations implemented on another object, while conductive effect is the effect produced by the conductive transformation.

When solving a contradictory problem, sometimes the contradiction cannot be solved directly by implementing certain transformation, but can be solved by the conductive transformation consequently occurred. Such thinking modes to solve contradictory problems by utilizing conductive transformations are referred to as conductive thinking modes. For easy mastering by readers, we express such thinking modes by formalization as follows:

Suppose certain object is Γ_1 (Γ_1 may be basic-element, universe of discourse or dependent criterion), and the contradiction cannot be solved by transformation $\varphi\Gamma_1 = \Gamma_1'$, if $\Gamma_1 \sim \Gamma_2$, we can find transformation $T_\varphi \Leftarrow \varphi$, $T_\varphi\Gamma_2 = \Gamma_2'$, to solve the contradictory problem. The mode of finding and implementing T_φ is conductive thinking mode.

When using the conductive thinking mode, it should be noticed whether the adopted conductive transformation can cause secondary conductive transformations. If yes, it should be further noticed whether the effect of the secondary transformation is positive or negative. If it is a negative effect, it must be prudently considered whether it's necessary to adopt such thinking mode, and if it's necessary, it should be considered to prepare corresponding coordination scheme, to avoid the occurrence of undesirable effects.

[Example 3.31] On the eve of the Mid-autumn Festival 2001, a foods limited liability company suddenly became a public spotlight, because it's broadcasted by certain TV station that the company produced moon cakes by using the remaining material of the last year. For a while the whole environment was forming a tremendous pressure for the company's production and sales, and the company's awkward and stagnant crisis-treating strategy worsened the situation just like icing on the cake. Finally, "a fire on the city gate (company A) brought disaster to the fish in the moat" – significant influence on other domestic moon cake manufacturers. This case is analyzed by conductive thinking mode as follows.

(1) Transformation of one matter-element in correlation network will cause transformation of other matter-elements correlative to it

To construct a correlation network, let $O_1 =$"company A", $O_2 =$"moon cakes produced by O_1", $O_3 =$"remaining material of the last year used to produce O_2", to construct the following multi-dimensional matter-elements:

$$M_1 = \begin{bmatrix} O_1, & \text{product type}, & \text{moon cake} \\ & \text{brand name}, & \text{A} \\ & \text{sales volume}, & v_{13} \\ & \text{reputation}, & v_{14} \\ & \text{profit}, & v_{15} \end{bmatrix} = \begin{bmatrix} O_1, & c_{11}, & O_2 \\ & c_{12}, & v_{12} \\ & c_{13}, & v_{13} \\ & c_{14}, & v_{14} \\ & c_{15}, & v_{15} \end{bmatrix} = \begin{bmatrix} M_{11} \\ M_{12} \\ M_{13} \\ M_{14} \\ M_{15} \end{bmatrix}$$

$$M_2 = \begin{bmatrix} O_2, & \text{quality}, & v_{21} \\ & \text{raw material}, & v_{22} \\ & \text{unit price}, & v_{23} \end{bmatrix} = \begin{bmatrix} O_2, & c_{21}, & v_{21} \\ & c_{22}, & v_{22} \\ & c_{23}, & v_{23} \end{bmatrix} = \begin{bmatrix} M_{21} \\ M_{22} \\ M_{23} \end{bmatrix}$$

$$M_3 = \begin{bmatrix} O_3, & \text{quality}, & \text{nonconforming} \\ & \text{price}, & v_{32} \end{bmatrix} = \begin{bmatrix} O_3, & c_{31}, & v_{31} \\ & c_{32}, & v_{32} \end{bmatrix} = \begin{bmatrix} M_{31} \\ M_{32} \end{bmatrix}$$

According to divergence analysis principles, as to characteristic c_{11} (product type), matter-element M_1 's matter-element set of the same characteristic and value is

$$\{M_{11i_1}\}=\{\text{all manufacturer of moon cakes}\}=\left(O_{1i_1},\quad c_{11},\quad \text{moon cake}\right),\ (i_1 = 1, 2, 3, \cdots);$$

As to characteristic c_{12} (brand name), matter-element M_1 's matter-element set with the same characteristic and value is

$$\{M_{12i_2}\}=\{\text{all manufacturers of product brand A}\}=\left(O_{1i_2},\quad c_{12},\quad \text{A}\right),\quad (i_2 = 1, 2, 3, \cdots);$$

As to matter O_1, O_2, all its sub-matter-elements M_{13}, M_{14}, M_{15}, M_{21}, M_{22}, and M_{23} are correlative to M_{31} and M_{32}, i.e. we have the next correlation network

$$M_{15} \sim M_{13} \sim M_{14} \sim M_{21} \begin{cases} \sim M_{23} \sim M_{22} \sim M_3 \\ \\ \sim M_{31} \sim M_{32} \end{cases}$$

In this correlation network, when sub-matter-element M_{23} 's measure v_{21} changes (from new material of the current year to remaining material of the last year), each matter-element in the correlation network will change correspondingly, as a consequent.

To all ordinary consumers, M_3 is unknown, but the company is brought into a very disadvantageous situation by the exposure on TV.

(2) Negative conductive effect of the company's crisis-treating strategy

After occurrence of the crisis, company A mainly adopts two measures to treat the sudden crisis: ① alleging that producing moon cakes by using remaining material of the last year is a common practice in the industry with tactic understanding, not particular to our company, and the quality of remaining material of the last year is of no problem; ② sales of produced moon cakes by price reduction.

These two strategies can be summarized in two transformations:

We make $\varphi_1\ M_{31} = M'_{31} = (O_3, \text{quality}, \text{conforming})$, i.e. "alleging the quality of remaining material of the last year is no problem";

$\varphi_2\ M_{32} = M'_{32} = (O_3, \text{price}, v'_{32})$, $v'_{32} < v_{32}$, i.e. "sales by price reduction".

It's obvious that, because of $M_{31} \sim M_{21}$, there must be conductive transformations T_{21}, $\varphi_1 \Rightarrow T_{21}$, to let

$$T_{21}\ M_{21} = M'_{21} = (O_2,\ \text{quality},\ v'_{21}),$$

But actually, $v'_{21} = v_{21}$, so its 1-order conductive effect is

$$dT_{\varphi_1(1)}(c_{21}) = v_{21} - v_{21} = 0$$

It can be seen that the strategy φ_1 adopted by company A is of no effect, i.e. of no help for solving the problem.

For transformation φ_2, we obviously have

$$\varphi_2 \Rightarrow \{T_{13},\quad T_{14},\quad T_{15}\}$$

i.e.

$\varphi_2 \Rightarrow T_{13}$, $T_{13}\ M_{13} = M'_{13} = (O_1,\ \ c_{13},\ \ v'_{13})$, where $v'_{13} < v_{13}$, with 1-order conductive effect:

$$dT_{\varphi_2(1)}(c_{13}) = v'_{13} - v_{13} < 0$$

$\varphi_2 \Rightarrow T_{14}$, $T_{14}\ M_{14} = M'_{14} = (O_1,\ \ c_{14},\ \ v'_{14})$, where $v'_{14} < v_{14}$, with 1-order conductive effect:

$$dT_{\varphi_2(1)}(c_{14}) = v'_{14} - v_{14} < 0$$

$\varphi_2 \Rightarrow T_{15}$, $T_{15}\ M_{15} = M'_{15} = (O_1,\ \ c_{15},\ \ v'_{15})$, where $v'_{15} < v_{15}$, with 1-order conductive effect:

$$dT_{\varphi_2(1)}(c_{15}) = v'_{15} - v_{15} < 0$$

So the 1-order conductive effect of transformation φ_2 is

$$dT_{\varphi_2(1)}(c) = dT_{\varphi_2(1)}(c_{13}) + dT_{\varphi_2(1)}(c_{14}) + dT_{\varphi_2(1)}(c_{15})$$

$$=(v'_{13} - v_{13}) + (v'_{14} - v_{14}) + (v'_{15} - v_{15}) < 0$$

It can be seen that the sales strategy of price reduction φ_2 adopted by company A not only fails to solve the problem, but produces a negative function.

Total effect of 1-order conduction:

$$dT_{\varphi(1)}(c) = dT_{\varphi_1(1)}(c_{21}) + dT_{\varphi_2(1)}(c) = 0 + (v'_{13} - v_{13}) + (v'_{14} - v_{14}) + (v'_{15} - v_{15}) < 0$$

Therefore, the measures adopted by company A not only fail to solve the existing problem, but make it worse.

Chapter 4 Solving Methods of Contradictory Problems

The world is full of contradictions. The human beings since appearance have been utilizing various transformation methods for survival and development to deal with assorted contradictory problems, transforming the incompatible to compatible, antithesis to coexistence. Contradiction, transformation and unity run through the whole developing process of human society.

Contradictory problems, as the study objects of Extenics, can be divided into three classes: the first class is the problems with subjective and objective contradictions, or incompatible problems for short; the second class is the problems with subjective and subjective contradictions, or antithetical problems for short; the third class is the problems with objective contradictions that are naturally existing without human intervention. Extenics mainly studies the contradictory problems of the first and second classes.

In order to study the solving methods of contradictory problems, this chapter first introduces the contradictory problem's extension model and its modeling method. It discusses the relation and transformation between contradictory problems and the complicated contradictory problems, and then provides the solving method of incompatible problems – extension strategy generating methods and the solving methods of antithetical problems – transforming bridge methods, finally introduces the preliminary study on the treatment of contradictory problems by computers.

4.1 Definition and Extension Model of Contradictory Problems

To properly solve the contradictory problems and establish the contradictory problems' model, the contradictory problems must be defined first as appropriate. This section first introduces the definition of problems and then respectively establishes the extension model of incompatible problems and antithetical problems, as the basis for solving the contradictory problems.

4.1.1 Defining Problems

Accurately defining a problem is the basis for problem solving, for which, the problems' purpose and condition must defined first. To define the purpose, the purpose must be reified as a goal, i.e. identified in a specific mode. The reification and quantification of the goal can increase the possibilities to meet the purpose.

1. Defining goals

(1) Importance of Setting the Goal

The goal is the basis of our action. It's well said in an English proverb that "to a crazy ship all winds are contrary." Like a high jumper without a crossbar before him, who freely jumps without a goal, it may be confirmed that he's never achieved a good jumping record.

(2) Must clarify the Goal

Goal generates belief, and the clearer goal, the firmer belief. An unclear goal can be hardly achieved. Florence Chadwick, an American at age 34 – the first woman swam across the English Channel, decided to challenge a longer channel – Catalina Channel, i.e. to swim to the California coast from Catalina that is 21 miles away in the west. On that day, the fog was so dense on the sea, she could hardly see her support boats, and her body was numbed by cold water. Fifteen hours had past, she felt tired and cold, and finally decided to quit and asked to be pulled on the support boat. Her trainer and her mother on the boat told her that it wasn't much farther and urged her not to quit. She looked toward the California coast, but all she could see was fog! After swimming 15 hours and 55 minutes, she was pulled on the boat – when she was only half a mile from the California coast! Later she concluded that what caused her to give up halfway was not fatigue, nor coldness, but there no goal could be seen in the dense fog. The goal was at a loss, so her belief was shaken. Two months later, she successfully swam through the same channel.

In the same way, setting a clear and accurate goal is the prerequisite to solve a problem or achieve certain effects, and also the basis for evaluating the decision-making scheme and assessing the implementation result. Hence, clarification of a goal is easy for result evaluation.

(3) Formalization and Digitalization of the Goal

Goal setting is the key to effectively finding a clue and a creative idea for problem solving. The goal can also be served as the decisive indicator in selecting the scheme with high realizability and good efficiency.

The goal can be really clarified and the problem model can be properly established only by formalizing and digitizing the goal. If the goal is abstract, it can be hardly determined that what is the degree of the key element, tool and personnel to be combined to meet the goal.

For example, the goal "to significantly reduce the cost as far as possible" is not clear enough, and if changed as "to reduce the cost by about 20%", then the goal can be clarified as:

$$g=\begin{bmatrix} \text{reduce}, & \text{dominating object}, & \text{cost} \\ & \text{range}, & \text{about } 20\% \end{bmatrix},$$

which is a clarified and formalized goal.

(4) Clarification of Relation between Goals

When determining the goal, the goals may be many. Here the hierarchy of goals should be determined by implication analysis methods, and the priority of goals at the same hierarchy should be determined as well. If the most superior goal is g , the goals implication system is:

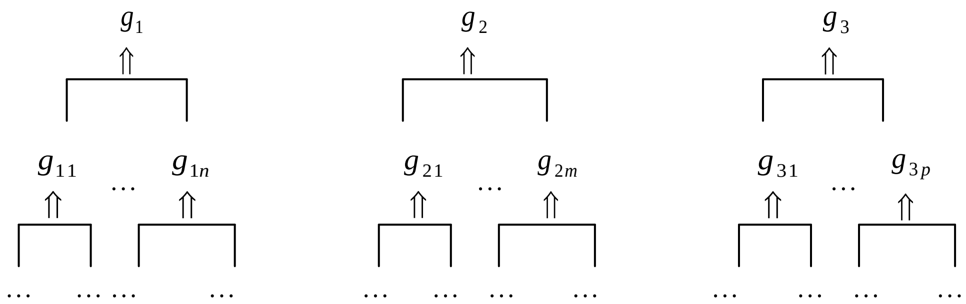
$$\begin{array}{c} g \\ \Uparrow \\ \begin{array}{ccc} g_1 & \cdots\cdots & g_n \\ \Uparrow & & \Uparrow \end{array} \\ \begin{array}{cccccc} g_{11} & \cdots & g_{1m} & g_{n1} & \cdots & g_{np} \end{array} \end{array}$$

The contradiction between the goal and condition, i.e. the incompatible problem is mostly considered by us in general. Here the multiple goals of the same subject should not be contradictory. If the different goals of two subjects or two goals of the same subject should be considered under the same condition, in case the goals are contradictory, it's an antithetical problem.

The goals should be achieved step by step from the inferior one to the superior one, while the setting of goals is hierarchical decomposition from the superior one to the inferior one.

All goals constitute an implication system of goals. The achievement of the inferior goal implies the achievement of the superior goal, while certain correlations may exist between the goals at the same hierarchy.

If there is only one superior goal, it's called the problem with the single goal; if there are multiple superior goals, it's called the problem with multiple goals. The implication system of the problem with multiple goals is shown in the following figures:



Since the goals can be divided into single goals, multiple goals, stage goals and long-term goals, local goals and global goals, the relation between the goals must be clarified at the beginning of problem solving.

For example, in general, it's hard to simultaneously meet the two goals "to double the sales volume" and "to double the gross profits" by the strategy of price reduction, i.e. the goals:

$$g_1 = \begin{bmatrix} \text{improve}, & \text{dominating object}, & \text{sales volume} \\ & \text{degree}, & \text{double} \end{bmatrix}$$

$$g_2 = \begin{bmatrix} \text{increase}, & \text{dominating object}, & \text{gross profit} \\ & \text{degree}, & \text{double} \end{bmatrix}$$

When the current product price is reduced for competitiveness, the gross profit will be inevitably reduced, so g_1 and g_2 can be reconcilable only in the case of significant progress in batch production efficiency, technological revolution and sales reform, or the result of doubled gross profits can be hardly achieved by low pricing. Here g_1 and g_2 can be simultaneously realized only when the conditions are transformed. Hence, such goals should not be determined readily, but determined after definition of conditions. In case g_1 and g_2 are contradictory subject to the conditions that cannot be transformed, we'd better select one from g_1 and g_2, and focus on one goal, for an easy solution to the problem.

If the determined goals are g_1, g_2 and g_3, we must determine the goal measuring conditions, and then determine the priority of the goals according to the different weights of the measuring conditions. If g_1 is determined as the first goal, we should first consider g_1 as the absolute superior goal, and then add g_2 and g_3 according to their priority of importance.

For example, an enterprise's goal is:

$$g_1 = \begin{bmatrix} \text{maintain}, & \text{dominating object}, & \text{market share} \\ & \text{location}, & \text{district A} \\ & \text{degree}, & 5\% \end{bmatrix}$$

$$g_2 = \begin{bmatrix} \text{maintain}, & \text{dominating object}, & \text{retail outlets} \\ & \text{quantity}, & 500 \end{bmatrix}$$

$$g_3 = \begin{bmatrix} \text{create}, & \text{dominating object}, & \text{basis for sales} \\ & \text{receiving object}, & \text{new product P} \end{bmatrix}$$

According to marketing knowledge, the priority of these three goals can be determined as g_1, g_2 and g_3.

(5) Types of Relations between Goals

Coordination in multiple respects should be taken into account to solve a problem; to this end, we must study the relations between goals, which can be divided into:

a) Subordinate Relation and Parallel Relations

If goal g_1 is part of g_2 (or g_2 is part of g_1), we say g_1 and g_2 are in subordinate relation; otherwise, they are in parallel relation.

The subordinate relation is the relation between superior goals and inferior goals in terms of hierarchy (such as the above implication system of goals); is the relation between long-term goals and stage goals in terms of time; and the relation between local goals and global goals in terms of the system. For example, the goal of an enterprise and the goals of its departments are in the relation between global goals and local goals. In general, the inferior, stage and local goals must serve for the realization of superior, long-term and global goals, in other words, must be helpful for the realization of superior, long-term and global goals.

In parallel relation, there may be dependent goals and independent goals. For example, among the goals in parallel relations at the same hierarchy, some goals may be dependent as well.

b) Antithetical Relation and Coexistent Relations

If goals g_1 and g_2 cannot be simultaneous achieved under certain conditions, we say g_1 and g_2 are in antithetical relation; otherwise they are in coexistent relation.

(6) Steps for Defining Goals

According to the above analysis, the steps for defining goals are shown as Figure 4.1.

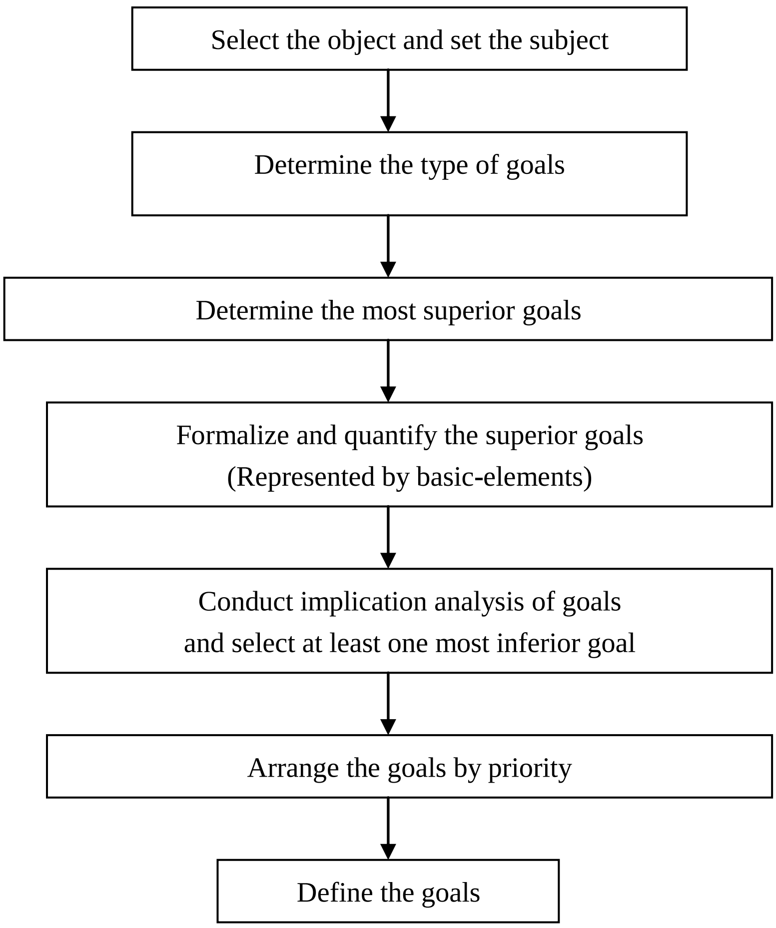


Figure 4.1 Flowchart of Goals Defining

2. Defining conditions

Conditions should be analyzed and defined after the definition of goals. Conditions include resource conditions and environment conditions, and the former includes internal resources and external resources, while the latter includes the internal environment and the external environment. Conditions mostly exist objectively, but can be created and transformed. Among the multitude of conditions, some are favorable for goal achievement, while some are not; some are compatible with the goal, while some are contradictory; some are nonrestrictive conditions, while some are restrictive. All conditions must be defined explicitly.

Steps for defining conditions:

(1) Collect goal-related information.

(2) Analyze the conditions required to achieve the goal $l_i (i = 1, 2, \cdots, n)$.

(3) Sort out l_i-related information, and determine the actual condition l_i' that corresponds to l_i.

(4) Analyze the differences between l_i' and l_i to determine whether l_i' is a restrictive or nonrestrictive condition.

(5) Express l_i' in a formalized basic-element to define the condition-involved matter, action and corresponding characteristic and measure.

(6) Select the main favorable conditions and main restrictive conditions that are closely related to the goal.

One important step in defining conditions is the formalized expressions of conditions in basic-elements, by which the conditions can be digitized as far as possible, to facilitate the subsequent analysis of problems and achievements of the planned goal by full use and extension of the conditions.

For the objectively existing or artificially given conditions that are limited, the achievement of a goal is restricted accordingly. When determining the restrictive condition, we should pay attention to clarify the nature of the restriction: elastic or rigid restriction; latent or apparent restriction; indefinite or definite restriction. Only the correct determination of the nature of restriction is helpful for the analysis of a condition.

3. Defining problems

As mentioned above, Extenics mainly studies how to transform the contradictory problems. After the goals and conditions are defined, we should first establish the extension model of the problem:

$$P = g * l$$

or

$$P = (g_1 \wedge g_2) * l$$

where g , g_1 and g_2 are goals, and l is condition, which can be expressed in formalized basic-elements.

If under condition *l*, the goal *g* cannot be achieved, we call the problem $P = g * l$ incompatible problem, denoted as $g \uparrow l$; if under condition *l*, the goals g_1 and g_2 cannot be simultaneously achieved; we call the problem $P=(g_1\wedge g_2)*l$ antithetical problem, denoted as $(g_1\wedge g_2)\uparrow l$.

In case of multiple goals and conditions, the extension model is:

$$P=(g_1\wedge g_2\wedge\cdots\wedge g_n)*(l_1\wedge l_2\wedge\cdots\wedge l_m),$$
$$(g_1\wedge g_2\wedge\cdots\wedge g_n)\uparrow(l_1\wedge l_2\wedge\cdots\wedge l_m)$$

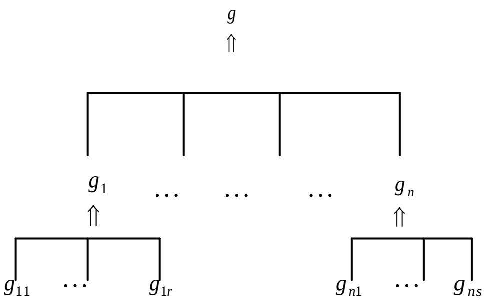
The quantitative determination method of incompatible and antithetical problems will be introduced in 4.1.2 and 4.1.3 of this section. In general, simpler problems can be easily determined whether they are incompatible or antithetical problems by subjective determination methods.

Actually many problems are very complicated. When defining problems, if using the thinking that “art is good for strength”, we will achieve an unexpected effect.

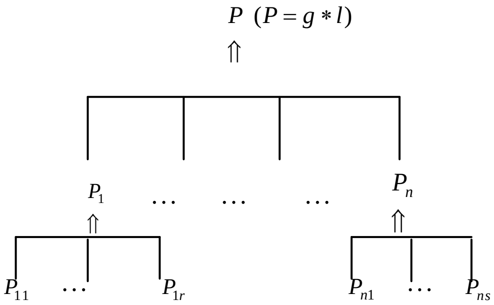
To define problems, we first introduce the concepts of implication system of problems and key problems. Although the implication includes “AND implications” and “OR implications”, we only take “AND implications” as the example in the following for easy explanation. The case of “OR implication” may be explained by the interested readers themselves.

(1) Implication System of Problems

Supposing g is global goal and l is condition, the “AND implication system” of goal is:



Then, the corresponding “AND implication system” of problem is:



and we call the problem set {$P_{11},\ldots,P_{1r},\ldots, P_{n1},\ldots, P_{ns}$} the most inferior problem set in the implication system of problems. Similar to the writing of basic-element and implication, the above problem and implication can be denoted by:

$$P_{11}\wedge\ldots\wedge P_{1r}\wedge\ldots\wedge P_{n1}\wedge\ldots\wedge P_{ns}\Rightarrow P$$

(2) Three Types of Defining Problems

a) Defining Problems with Single Local Goals

These kinds of problems are very common, such as the preparation of plans, pricing and promotion program of a product project which are problems with single goal in many cases.

Suppose the goal is g and the condition is l, we can establish the problem's extension model:

$$P = g * l$$

and then judge whether the problem is an incompatible problem or not. After these two steps are completed, it's considered that the problem is defined.

b) Defining Problems with Multiple Local Goals

Suppose the goals are g_1, g_2, …, g_n and the condition is l.

① When $n = 2$, the established extension model of the problem is

$$P = (g_1 \wedge g_2) * l$$

Now there are two cases:

i) If $(g_1 \wedge g_2) \uparrow l$, the problem is an antithetical problem;

ii) If $g_i \uparrow l \quad (i = 1,\ 2)$, the problem can be decomposed into two incompatible problems, i.e.

$$P = (g_1 * l) \wedge (g_2 * l), \quad P // \{P_1, P_2\}$$

where $P_1 = g_1 * l,\ P_2 = g_2 * l$. Now, it can be considered to discard a problem first. If it's possible, it's considered the problem is defined. If it's not possible, we should determine the priority of the two problems according to their degree of importance; or look for the inferior problem by the implication analysis of the problem.

② When $n \geq 3$, the established extension model of the problem is

$$P = (g_1 \wedge g_2 \wedge \cdots \wedge g_n) * l$$

i) If $(g_i \wedge g_j) \uparrow l \quad (i < j,\ i, j = 1,\ 2,\ \cdots, n)$, the problem P is an antithetical problem with multiple goals. Now we must first determine the core problem in the problems $P_{ij} \quad (i < j,\ i, j = 1,\ 2,\ \cdots, n)$ corresponding to goal g_i and g_j, and then obtain the degree of coexistence between g_i and g_j, so as to determine each antithetical problem. For definition and determination methods of the core problem, see 4.1.3.

ii) If $g_i \uparrow l \quad (i = 1,\ 2,\ \cdots, n)$, the problem P is an incompatible problem with multiple goals. We can determine the core problem of the incompatible problem by referencing the corresponding method given in **a)**.

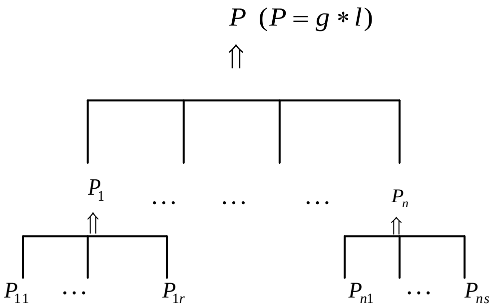
Particular attention should be paid to the following: no matter the problem with a single local goal or the problem with a multiple local goal, the relation between the local goal and the global goal should be analyzed, and if the achievement of local goal affects the achievement of global goal, the scheme will not be satisfactory. Hence, sometimes the global goal can serve as a measuring condition, to allow the implementation of the solution to the local goal to play a positive role in the realization of the global goal.

c) Defining Global Problems

Suppose goal g is a global goal, and condition is l, we can establish the problem's extension model

$$P = g * l$$

First conduct implication analysis of the problem, and establish the implication system of the problem, to look for the inferior problem:



and then determine the core problem of the inferior problems.

If we properly defined the problem, simplified, clarified and formalized the problem and found the key problem to be solved, it can be said that half of the solution to the problem is obtained. The next half is extensible analysis and extension transformation of the problem, by which the strategy to solve the problem will be generated.

4.1.2 Extension Model of Incompatible Problem

There are three kinds of thinking to solve incompatible problems: (1) to solve the contradiction through transformation of conditions, with the same goal; (2) to solve the contradictory problems through the transformation of a goal, with the same condition; (3) to solve the contradictory problems, with the goal and condition simultaneously changed.

When solving the contradictory problem through the transformation of a condition, we can establish extension set with the condition as its object and the measure range necessary to achieve the goal as its restriction, and then look for the transformation to transform the incompatible problem to a compatible problem.

When solving the contradictory problem through the transformation of a goal, we can establish extension set with the basic-elements of the goal that corresponds to the condition as its object, and the measure ranges that can be provided by the condition as its restriction, and then look for the transformation to transform the incompatible problem to a compatible problem.

Next we provide the definition of an incompatible problem within the individual case (1) only.

Definition 4.1 Given problem $P = G * L$, wherein G, L may be the basic-element, compound element or the operation equation of basic-elements. Suppose c_0 is evaluation characteristic, $c_{0\mathrm{s}}$ is the required characteristic that the object Z_g about c_0 when the goal G is achieved, the positive field is X_0, the value range is X, and $X_0 \subset X$, $c_{0\mathrm{t}}$ is the characteristic provided by the object Z_0 about Z_0 in the condition L, and the measure is $c_{0\mathrm{t}}$ (Z_0), denoted by

$$g_0 = (Z_g,\ c_{0\mathrm{s}},\ X_0),\ l_0 = (Z_0,\ c_{0\mathrm{t}},\ c_{0\mathrm{t}}\ (Z_0)),$$

we call $P_0 = g_0 * l_0$ the core problem of problem P.

Make $W=\{l \mid l=(Z,c_0,c_0(Z))=(Z,c_0,x), Z\in\{M,A,R\}, Z_0 \dashv Z\}$, with $X_0(X_0 \subset X)$ as positive field, establish the compatibility function $k(x)$ of l about c_0 (for the establishment method of compatibility function, reference to the establishment method of dependent function given in 2.7), and make extension set

$$\tilde{E}(T)=\{ (l, y, y')|l\in W, y=K(l)= k(x)\in(-\infty, +\infty); T_l l\in T_W W, y'=T_K K(T_l l)\in(-\infty, +\infty)\}$$

denoted by $K_0(P)= K(l_0)= k[c_{0t}(Z_0)]$, and we call it the degree of compatibility of problem P. If $K_0(P)<0$, the problem P is an incompatible problem; if $K_0(P)>0$, the problem P is a compatible problem; if $K_0(P)=0$, the problem P is a critical problem.

In extension set $\tilde{E}(T)$, $T=(T_W, T_K, T_l)$, where T_W is the transformation of universe of discourse W, T_K is the transformation of compatibility function, and T_l is the transformation of element l.

Regarding the relation between the original problem and the core problem of incompatible problems, the proposition is as follows:

Proposition 4.1 Suppose the core problem $P=G*L$ is $P_0=g_0*l_0$, then $(g_0\downarrow l_0)\Rightarrow(G\downarrow L)$.

Definition 4.2 (solution transformation of incompatible problem) As to the problem $P=G*L$, $K_0(P)=K(l_0)<0$, i.e. the problem P is an incompatible problem. If there is extension transformation $T=(T_W, T_k, T_l)$ to let

$$T_K K(T_{l_0} l_0)= K'(T_{l_0} l_0)= K'(l_0')>0$$

then we call T solution transformation of the incompatible problem P, wherein

$$T=\begin{bmatrix} O_T, & \text{dominating object}, & v_1 \\ & \text{receiving object}, & v_2 \\ & \text{acting object}, & v_3 \\ & \text{method}, & v_4 \\ & \text{tool}, & v_5 \\ & \text{time}, & v_6 \\ & \text{location}, & v_7 \end{bmatrix} = \begin{bmatrix} O_T, & c_1, & v_1 \\ & c_2, & v_2 \\ & c_3, & v_3 \\ & c_4, & v_4 \\ & c_5, & v_5 \\ & c_6, & v_6 \\ & c_7, & v_7 \end{bmatrix}$$

O_T is the name of the transformation, $v_1\in\{l, K, W\}$, v_2 and v_3 qualitatively specify the premise and result of the transformation, and the operator of the transformation, v_4 and v_5 specify the method and tool of the transformation, being the two key elements to realize the transformation T. The measuring range of v_4, v_5, v_6, v_7 is determined by the subjective requirement of people, and the limited historical literature or objective laws.

4.1.3 Extension Models of Antithetical Problems

To establish the extension model of antithetical problem, we first give the definition of antithetical problem.

Definition 4.3 (definition of antithetical problem) Given problem $P=(G_1\wedge G_2)*L$, wherein G_1, G_2, L are basic-elements, compound element or the operation formula of basic-elements. Suppose c_0 is an evaluation characteristic, Z_1 and Z_2 are the objects involved by the goals G_1 and G_2, c_{0s} is the required characteristic of Z_1 and Z_2 about c_0, the positive domain of values is X_{10}, X_{20}, the value range is 为 X_1, X_2, and $X_{10}\subset X_1$, $X_{20}\subset X_2$. The object element is

$$g_{10}=(Z_{g1}, c_{0s}, X_{10}),\ g_{20}=(Z_{g2}, c_{0s}, X_{20}),$$

c_{0t} is the characteristic of the object of condition L that corresponds to the goal about c_0, measure is $c_{0t}\,(Z_{10})$, $c_{0t}\,(Z_{20})$, and the condition element is denoted by

$$l_{10}=(Z_{10}, c_{0t}, c_{0t}\,(Z_{10})),\ l_{20}=(Z_{20}, c_{0t}, c_{0t}\,(Z_{20})).$$

Then we call $P_0=(g_{10}\wedge g_{20})*(l_{10}\wedge l_{20})$ the core problem of problem P.

Denote

$$U=\{l_1\,|\,l_1=(Z_1,c_0,x_1),Z_1\in\{M,A,R\},\ Z_{10}\dashv Z_1\}$$

$$V=\{l_2\,|\,l_2=(Z_2,c_0,x_2),Z_2\in\{M,A,R\},\ Z_{20}\dashv Z_2\}$$

Make binary extension set

$$\tilde{E}\,(l_1, l_2)=\{\ ((l_1, l_2), y, y')|l_1\in U,\ l_2\in V,\ y=K(l_1, l_2)= k(x_1,x_2);$$

$$T_{l_1}l_1\in T_U U,\ \ T_{l_2}l_2\in T_V V,\ y'=T_K\,K(T_{l_1}l_1,\ \ T_{l_2}l_2)\ =k'(x_1',x_2')\ \}$$

and call

$$K_0(P)= K(l_{10}, l_{20}) = k[c_{0t}\,(Z_{10}), c_{0t}\,(Z_{20})]$$

the degree of coexistence of problem P. If $K_0(P)>0$, we call P a coexistent problem; if $K_0(P)<0$, we call P an antithetical problem; if $K_0\,(P)=0$, we call P *a* critical problem.

Regarding the relation between the original problem and the core problem of antithetical problem, the proposition is as follows:

Proposition 4.2 Suppose the core problem of a problem $P=(G_1\wedge G_2)*L$ is $P_0=(g_{10}\wedge g_{20})*(l_{10}\wedge l_{20})$, then

$$((g_{10}\wedge g_{20})\downarrow(l_{10}\wedge l_{20}))\Rightarrow((G_1\wedge G_2)\downarrow L).$$

Definition 4.4 (solution transformation of antithetical problem) Given problem $P=(G_1\wedge G_2)*L$, $K_0(P)<0$, in case of transformation

$$T=(T_{l_1},\ T_{l_2},\ T_K, (T_U, T_V))$$

to let

$$T_K\,K(T_{l_1}l_1,\ \ T_{l_2}l_2)=K'\,(T_{l_1}l_1,\ \ T_{l_2}l_2)= k'(x_1', x_2')>0$$

we call *T* solution transformation of the antithetical problem *P*.

4.2 Operation, Extension and Transformation of Contradictory Problems

In the real world, the contradictory problems are extremely complicated in general, and the solution paths are numerous as well. Hence, we should not only study the solutions to the previous simple problems, but also study the operation of contradictory problems, the solution to complicated contradictory problems and the conductive function of the extension transformation on things related to the problem to be solved.

4.2.1. Relation of Contradictory Problems

During the process of solving the contradictory problem, the problem must be transformed. Hence, we should first study the relation between problems:

1. Implication

Definition 4. 5 (implication) If problem P_1 is realized so that problem P_2 is realized, we say the problem P_1 **implies** P_2, denoted as $P_1 \Rightarrow P_2$.

It can easily prove that the implicative relation has the following transitivity:

Nature 4.1 If $P_1 \Rightarrow P_2$, $P_2 \Rightarrow P_3$, then $P_1 \Rightarrow P_3$.

Such transitivity runs through the whole process of solving contradictory problems.

2. Equivalence

Definition 4. 6 (equivalence) Given two problems P_1 and P_2, if $P_1 \Rightarrow P_2$, and $P_2 \Rightarrow P_1$, then we say P_1 and P_2 are **equivalent,** denoted as $P_1 \Leftrightarrow P_2$.

3. Equality

Definition 4. 7 (equality) Given two incompatible problems $P_1 = g_1 * l_1$ and $P_2 = g_2 * l_2$, if $g_1 = g_2$, $l_1 = l_2$, we say P_1 and P_2 are equal, denoted as $P_1 = P_2$.

Given two antithetical problems $P_1 = (g_{11} \wedge g_{12}) * l_1$, $P_2 = (g_{21} \wedge g_{22}) * l_2$, if $g_{11} = g_{21}$, $g_{12} = g_{22}$, $l_1 = l_2$, we say P_1 and P_2 are equal, denoted as $P_1 = P_2$.

4.2.2 Operation of Contradictory Problems

1. OR problem

Definition4. 8 (OR problem) The **OR problem** of problems P_1 and P_2 refers to the problem that is considered realized once any of P_1 and P_2 is realized, denoted as $P_1 \vee P_2$.

2. AND problem

Definition4. 9 (AND problem) The **AND problem** of problems P_1 and P_1 refers to the problem that is considered realized only when both P_1 and P_2 are realized, denoted as $P_1 \wedge P_2$.

3. NOR problem

Definition4. 10 (NOR problem) Given problem $P = g * l$, we call problem $\bar{g} * l$ NOR problem of *P*, denoted as $\bar{P} = \bar{g} * l$.

From the definitions of "OR problem" and "AND problem", it's easy to obtain the following logical operation:

(1) If $P_1 = g_1 * l_0$, $P_2 = g_2 * l_0$, then

$$P_1 \vee P_2 = (g_1 * l_0) \vee (g_2 * l_0) = (g_1 \vee \mathrm{g}_2) * l_0;$$

$$P_1 \wedge P_2 = (g_1 * l_0) \wedge (g_2 * l_0) = (g_1 \wedge \mathrm{g}_2) * l_0.$$

(2) If $P_1 = g_0 * l_1$, $P_2 = g_0 * l_2$, then

$$P_1 \vee P_2 = (g_0 * l_1) \vee (g_0 * l_2) = g_0 * (l_1 \vee l_2);$$

$$P_1 \wedge P_2 = (g_0 * l_1) \wedge (g_0 * l_2) = g_0 * (l_1 \wedge l_2).$$

4. Complex problem

Definition 4.11 (complex problem) In the problem $g * l$, if g or l is linked by several basic-elements using the logical symbols of $\wedge$, $\vee$ and $^{-}$ (such as $g = g_1 \vee (g_2 \wedge g_3)$, $l = l_1 \vee (l_2 \vee l_3)$), we call *P* complex problem, denoted by

$$P = \hat{g} * \hat{l} = g(\wedge, \vee, ^{-}) * l(\wedge, \vee, ^{-})$$

wherein $\hat{g} = g(\wedge, \vee, ^{-})$, $\hat{l} = l(\wedge, \vee, ^{-})$, indicate the goal is linked by $g_1, g_2, \ldots, g_m$ using logical symbols, and the condition is linked by the logical symbols of $l_1, l_2, \ldots, l_n$. We call $\hat{g}$ the logical link form of $g_1, g_2, \ldots, g_m$, and $\hat{l}$ the logical link form of $l_1, l_2, \ldots, l_n$.

Definition 4.12 (logical link form of problem) If problem P is linked by problems $P_1, P_2, \ldots, P_n$ using the logical symbols of $\wedge$, $\vee$ and $^{-}$, we call P the logical link form of $P_1, P_2, \ldots, P_n$ ($n \geq 1$), denoted by $\hat{P} = P_i(\wedge, \vee, ^{-})$.

Definition 4.13 (normal form) If in the problem's logical form $\hat{P} = P_i(\wedge, \vee, ^{-})$, all $P_1, P_2, \ldots, P_n$ are basic problems, we call P normal form.

4.2.3 Extension of Problems

In Extenics, the purpose of the study on contradictory problems is to solve them. According to the definition of a problem: $P = G * L$, in which both goal G and condition L can be expressed by formalized basic-elements or the compound of basic-elements, and according to the extensible reasoning of basic-elements and compound element, we can obtain the extensible reasoning rule of the problem. And through the extensible reasoning rule of the problem, we obtain the divergent problem, correlative problem, implicative problem and opening-up problem of the original problem, so as to provide various paths to solve the contradictory problems.

1. Divergent problems

Definition 4.14 Suppose $P_0 = g_0 * l_0$, wherein both g_0 and l_0 are basic-elements or compound elements. According to the divergence rule:

$$l_0 \dashv \{l_1, l_2, \cdots, l_m\}$$

we call $P_j = g_0 * l_j (j = 1, 2, \cdots, m)$ the divergent problem of P_0 about condition l_0, denoted by

$$P_0 \dashv \{P_j, j = 1, 2, \cdots, m\}.$$

According to the divergence rule: $g_0 \dashv \{g_1, g_2, ..., g_n\}$, we call $P_i = g_i * l_0 (i = 1, 2, \cdots, n)$ the divergent problem of P_0 about goal g_0, denoted by

$$P_0 \dashv \{P_i, i = 1, 2, \cdots, n\}.$$

According to the divergence rule:

$$l_0 \dashv \{l_1, l_2, \cdots, l_m\}, \quad g_0 \dashv \{g_1, g_2, ..., g_n\},$$

we call $P_{ij} = g_i * l_j (i = 1, 2, \cdots, n; j = 1, 2, \cdots, m)$ the divergent problem of P_0 about goal g_0 and condition l_0, denoted by

$$P_0 \dashv \{P_{ij}, i = 1,2,\cdots,n; j = 1,2,\cdots,m\}.$$

2. Implicative problems

Definition 4.15 Given problem $P_0 = g_0 * l_0$, if there is g to let $g \Rightarrow g_0$, we call problem $P_g = g * l_0$ the implicative problem of P_0 about goal g_0. If there is l to let $l \Rightarrow l_0$, we call problem $P_l = g_0 * l$ the implicative problem of P_0 about condition l_0. If there are simultaneously g and l to let $g \Rightarrow g_0$ and $l \Rightarrow l_0$, we call problem $P = g * l$ the implicative problem of P_0. The above problems are denoted respectively by $P_g \Rightarrow P_0$, $P_l \Rightarrow P_0$, and $P \Rightarrow P_0$.

3. Correlative problems

Definition 4.16 Given problem $P_0 = g_0 * l_0$, if there is g to let $g_0 \sim g$, we call problem $P_g = g * l_0$ the correlative problem of P_0 about goal g_0. If there is l to let $l \sim l_0$, we call problem $P_l = g_0 * l$ the implicative problem of P_0 about condition l_0. If there are simultaneously g and l to let $g_0 \sim g$ and $l \sim l_0$, we call problem $P = g * l$ the correlative problem of P_0. The above problems can be denoted respectively by $P_g \sim P_0$, $P_l \sim P_0$, and $P \sim P_0$.

4. Opening-up problems

Definition 4.17 Given problem $P_0 = g_0 * l_0$, if there is g_0's combinable goal g_1, i.e. $g = g_0 \oplus g_1$, we call problem $P = g * l_0$ the combined problem of P_0 about goal g_0. If g_0 can be decomposed into g_1, g_2, g_n, we call problem $P_i = g_i * l_0$ (i=1,2, n) the decomposed problem of P_0 about goal g_0. If g_0 can be expanded as $\alpha g_0\ (\alpha > 1)$ or contracted as $\alpha g_0\ (0 < \alpha < 1)$, we call problem $P = \alpha g_0 * l_0$ the expanded/contracted problem of P_0 about goal g_0.

The combined, decomposed and expanded/contracted problems about the condition, or about the goal and the condition can be defined similarly, which are omitted.

4.2.4 Extension Transformations of Contradictory Problems

As to the given universe of discourse and dependent criterion, the transformations of goals or conditions for contradictory problems will lead to the transformation of the problems. Next we give the definitions of extension transformations of contradictory problems.

1. Extension transformations of incompatible problems

Definition 4.18 Given problem $P = g * l$, if $T_g g = g'$, the transformation that transforms P to $P' = g' * l$ is called the extension transformation of P about the goal, denoted by ${}_gT_P = (T_g, e)$. If $T_l l = l'$, the transformation that transforms P to $P' = g * l'$ is called the extension transformation of P about the condition, denoted by ${}_lT_P = (e, T_l)$. If $T_g g = g'$, $T_l l = l'$, the transformation that transforms P to $P' = g' * l'$ is called the extension transformation of P about the goal and the condition, denoted by ${}_{(g,l)}T_P = (T_g, T_l)$.

For easy writing, the extension transformation of the above problem is denoted by $T_P = (T_g, T_l)$ for short. $T_P = (T_g, e)$ and $T_P = (e, T_l)$ are its particular cases.

2. Extension transformations of antithetical problems

Definition 4.19 Given antithetical problem $P = (g_1 \wedge g_2) \uparrow l$, if $T_{g_1} g_1 = g_1'$, $T_{g_2} g_2 = g_2'$, and $g_1' \Rightarrow g_1$, $g_2' \Rightarrow g_2$, the transformation that transforms P to $P' = (g_1' \wedge g_2') * l$ is called the extension transformation about the goal, denoted by ${}_gT_P = (T_{g_1}, T_{g_2}, e)$. As a particular case, there may be $T_{g_1} = e$ or $T_{g_2} = e$.

Given antithetical problem $P = (g_1 \wedge g_2) \uparrow l$, if $T_l l = l'$, it's denoted by $P' = (g_1 \wedge g_2) * l'$, and the transformation that transforms P to P' is called extension transformation about the condition, denoted by ${}_lT_P = (e, e, T_l)$.

If $T_{g_1} g_1 = g_1'$, $T_{g_2} g_2 = g_2'$, $T_l l = l'$, and $g_1' \Rightarrow g_1$, $g_2' \Rightarrow g_2$, the transformation that transforms P to $P' = (g_1' \wedge g_2') * l'$ is called extension transformation of P, denoted by ${}_{(g,l)}T_P = (T_{g_1}, T_{g_2}, T_l)$.

For easy writing, the transformation of the above problem is denoted by $T_P = (T_{g_1}, T_{g_2}, T_l)$ for short.

The extension transformation of the above contradictory problems may be substitution transformation, increase/decrease transformation, expansion/contraction transformation, decomposition transformation or other basic transformation, or may be the operation of transformation, or conductive transformation, etc.

4.2.5 Conducted Contradictory Problem and Conducted Contradictory Problem Chain

1. Concepts of conducted contradictory problem and conducted contradictory problem chain

Since there is a network of correlations between things, the solution to a contradictory problem usually leads to a generation of a new contradictory problem. Therefore, when solving the previous contradictory problem, we must consider the treatment methods of the new contradictory problems that may be generated. For example, rob Peter to pay Paul, by which Paul is paid, but what about the robbed Peter? In order to describe such phenomena, we introduced the concepts of conducted contradictory problems and conducted contradictory problem chains.

Definition 4.20 (conducted contradictory problem) Given problem $P = G * L$, $K(P)$<0, $T_P = (T_G, T_L)$ is solution transformation of P, if there is a problem $P_0 = G_0 * L_0$, K_0 (P_0) >0, and $P_0 \sim P$. According to conductive rule: $T_P \Rightarrow_P T_{P_0}$, ${}_P T_{P_0} = ({}_G T_{G_0}, {}_L T_{L_0})$, let

$${}_P T_{P_0}(P_0)=({}_G T_{G_0} G_0)*({}_L T_{L_0} L_0)= G_1*L_1=P_1$$

If $K_0(P_1)$<0, we call P_1 conducted contradictory problem of T_P about P_0.

Among the conducted contradictory problems, a kind of problem is commonly found, i.e. after the original contradictory problem P is solved, because of the generation of a series of conductive transformations, a series of conducted contradictory problems are generated, which is referred to as a contradictory problem chain. Some contradictory problem chains eventually cause the original goal not to be achieved, i.e. under the new condition; new contradictory problems are generated against the achievement of the original goal. Next, the two cases are strictly defined.

Definition 4.21 (conducted contradictory problem chain) If T_P is the solution transformation of contradictory problem $P = G * L$, P_1 is the conducted contradictory problem of T_P about problem P_{01}, T_{P_1} is the solution transformation of P_1, P_2 is the conducted contradictory problem of T_{P_1} about problem P_{02}, …, T_{P_n} is the solution transformation of P_n, and P_{n+1} is the conducted contradictory problem of T_{P_n} about problem P_{0n}, we say P, P_1, P_2, …, P_{n+1} constitute a conducted contradictory problem chain, denoted by P-P_1-P_2-…-P_{n+1}, where $P_{i+1}={}_{P_i} T_{P_{0i+1}} P_{0i+1}$, i=0,1,2, …,n, P=P_0.

Definition 4.22 (conducted contradictory problem ring) If P-P_1-P_2-…-P_{n+1} is the conducted contradictory problem chain of the contradictory problem $P = G * L$, P_{n+1} is the conducted contradictory problem of T_{P_n} about problem P_{0n}, P_{n+1}=G*L_{n+1}, we say P-P_1-P_2-…-P_{n+1} constitute a conducted contradictory problem ring. It's obvious that the conducted contradictory problem ring is a particular case of the conducted contradictory problem chain.

2. Types of conducted contradictory problems

A conducted contradictory problem is resulted from the conductive transformation of the goal element or condition element of the related problem by the solution transformation of the original contradictory problem. Therefore, the study on the types of conducted contradictory problems plays an important role in determining to adopt which strategy to solve the contradictory problem.

Conducted contradictory problems can be divided into two types: the first type is resulted from the related problem of the original problem, and the second type is resulted from the conjugate problem of the original problem.

(1) Conducted Contradictory Problems Resulting from Related Problems

Given problem $P = G * L$, $K(P)<0$, if there is transformation T_P to let $K(T_P P)>0$, but as to another problem $P_0 = G_0 * L_0$, $K_0(P_0)>0$, and $P_0 \sim P$. According to the conductive rule: $T_P \Rightarrow {}_P T_{P_0}$, ${}_P T_{P_0} = ({}_G T_{G_0}, {}_L T_{L_0})$, let

$$ {}_G T_{G_0} G_0 = G_1, \quad {}_L T_{L_0} L_0 = L_1, $$

now, if $P_1 = ({}_G T_{G_0} G_0) * ({}_L T_{L_0} L_0) = G_1 * L_1$, and there is $K(P_1)<0$, then P_1 is the conducted contradictory problem resulted from related problems.

(2) Conducted Contradictory Problems Resulted from Conjugate Problems

Given problem $P = G * L$, $K(P)<0$, if there is transformation T_P, to let $K(T_P P)>0$, but as to certain conjugate problems $P_0 = \hat{G}_0 * L_0$ that corresponds to P, $K_0(P_0)>0$, and $P_0 \sim P$. According to the conjugate rule: $T_P \Rightarrow_P T_{P_0}$, let

$$ {}_P T_{P_0} P_0 = ({}_G T_{\hat{G}_0} \hat{G}_0) * ({}_L T_{L_0} L_0) = G_1 * L_1 = P_1 $$

and $K_0({}_P T_{P_0} P_0) = K_0(P_1)<0$, now, P_1 is conducted contradictory problem of T_P about the conjugate problem P_0, in which, G and $\hat{G}_0$ are conjugate basic-elements.

4.2.6 Contradictory Problem System

In the real world, there are assorted contradictory problems in a large-scale project or a region, and they are mutually associated. It's well said in the saying that there is a mountain of contradictions and a heap of problems. In order to describe this phenomenon, we propose the concept of contradictory problem systems. Practically, in a region, an enterprise, or an organization, etc. there are usually multiple goals G_1, G_2, …, G_m, and multiple conditions L_1, L_2, …, L_n. Since the goals and conditions are mutually associated, they constitute the problem system P. In such a problem system, there are both contradictory problems and non-contradictory problems, so they constitute a contradictory problem system. To solve the contradictory problem system, we should consider treatment of individual problems, and the association between problems, as well as the conducted contradictory problems resulting from the treatment. Therefore, the study on contradictory problem systems is extremely complicated work. A large amount of contradictory systems can be found in economy, management, control, inspection and artificial intelligence, which should be solved by utilizing the extension logic, extension set theory and basic-element theory, combined with comprehensive treatment by professional basic theories and methods, and aided by a computer as well. These works are to be further studied by the readers.

4.3 Incompatible Problem Solving Method

——Extension Strategy Generating Method

When introducing the extension model of incompatible problems in section 4.1, we have introduced three kinds of thinking to solve incompatible problems: (1) to solve the contradiction through the transformation of a condition, with the same goal; (2) to solve the contradictory problem through the transformation of a goal, with the same condition; (3) to solve the contradictory problem, with the goal and condition simultaneously changed.

No matter by any thinking to transform incompatible problem P to compatible, the key is to find the transformation T=(T_W,T_K,T_P) to let

$$T_K K(T_P P)=K'(P')>0.$$

The so-called extension strategy is the extension transformation or the operation equation of the extension transformation that changes the incompatible problem's compatibility from being less than or equal to 0 to be more than 0, i.e. the solution transformation of the incompatible problem. The extension strategy generating process is referred to as the generation of extension strategy.

The extension strategy generating method is the method to generate the solving strategy of incompatible problems by formalized and quantitative methods, on the basis of the basic thinking of Extenics, simulating human thinking. Through the establishment of extension models of an incompatible problem, it judges the contradictory degrees of the problem by calculating the problems compatibility using dependent function, conducts extensible analysis, conjugate analysis and extension transformation of the incompatible problem, and then evaluates its superiority, to obtain the preferred extension strategy to solve the incompatible problem.

Next we introduce the basic thinking and steps of extension strategy generation, and give examples.

4.3.1 Basic Thinking of Extension Strategy Generation

The theoretical basis of extension strategy generation is the extension theory, with the purpose to solve the incompatible problems, and the basic thinking is as follows:

(1) First define the goal and condition of the practical problem, and then establish the extension model of the problem by a basic-element expression system;

(2) Determine the problem's core problem according to the indicator provided by the practical problem and the value of the corresponding indicator required to achieve the goal (or the measuring range);

(3) Establish the compatibility function of the incompatible problem, and judge the problem incompatibility by calculation;

(4) Determine to first analyze the goal or the condition:

   1) To first analyze the problem's condition with the same goal, select the correlation analysis from extensible analysis, and establish the problem's correlation tree (net);

   2) To first analyze the problem's goal with the same condition, select the implication analysis from extensible analysis, and establish the problem's implication tree;

3) To analyze both the goal and the condition, first execute 1) and then 2), and jointly establish the problem's correlation-implication tree.

(5) Conduct divergence analysis and conjugate analysis of the leaves of the correlation tree or implication tree, conduct extension transformation, and then form the implication tree of conductive transformation according to the conductive transformation; the tree formed by extension transformation and conductive transformation is commonly referred to as the extension strategy generating tree;

(6) Calculate the value of the compatibility function of the problem formed after transformation, and if its compatibility is changed from being less than or equal to 0 before transformation to be more than 0 (note: some problems are considered compatible in case of 0, while some are not, so make a concrete analysis of a concrete problem), the extension transformation or the operation equation of the transformation is the extension strategy to solve the incompatible problem.

4.3.2 Specific Steps of Extension Strategy Generating Method

The basic steps to generate the extension strategy by extension method to solve the incompatible problem are as follows:

1. Define the problem's goal and condition by the definition method of contradictory problems, and express them by basic-elements

Suppose the problem's goal is G and condition is L, first express G and L by basic-elements:

$$G=(O_1, C_1, V_1), \quad L=(O_2, C_2, V_2)$$

2. Establish extension models of the problem and its core problem

Extension model of the problem is

$$P= G* L$$

Extension model of the core problem is

$$P_0= G_0* L_0$$

3. Establish a decision function of contradictory problems – compatibility functions

By using the establishment method of dependent function, according to the condition of the practical problem and the requirement to achieve the goal, establish compatibility function $K(P)$. If $K(P)<0$, we call problem P an incompatible problem; if $K(P)>0$, we call problem P a compatible problem; if $K(P)=0$, we call problem P a critical problem.

4. Implement extensible analysis of the problem according to the extensible analysis method of basic-elements

(1) To first analyze the problem's condition with the same goal, follow the steps:

1) Select correlation analysis and establish the correlation tree or correlative net of condition L_0:

$$L_0 \sim \begin{cases} L_{01} \sim \begin{cases} L_{011} \sim \cdots \\ \vdots \\ L_{01h_1} \sim \cdots \end{cases} \\ L_{02} \sim \cdots \\ \vdots \\ L_{0m} \sim \begin{cases} L_{0m1} \sim \cdots \\ \vdots \\ L_{0mh_m} \sim \cdots \end{cases} \end{cases}$$

The correlation tree is divided into directional correlation, mutual correlation, AND correlation and OR correlation. Please refer to the part of correlation analysis principle in 2.1.

2) Divergence analysis or conjugate analysis – by divergence analysis of the leaves of the problem's correlation tree or implication tree, taking divergence analysis of L_{011}, we can obtain the following divergence tree:

$$L_{011} -\!\!\left|\begin{cases} L_{0111} \\ L_{0112} \\ L_{0113} \\ \vdots \\ L_{011s_1} \end{cases}\right.$$

If L_{011} is a matter-element, we can also implement conjugate analysis, i.e. analysis of matter-elements in terms of imaginary and real, soft and hard, latent and apparent, and negative and positive, etc., to obtain various kinds of thinking to solve the incompatible problem, please read 3.3.

3) Opening-up analysis – combine or decompose the leaves of the problem's correlation tree after divergence, to obtain more paths to solve the incompatible problem.

(2) If a problem cannot be solved directly by analysis and transformation of the condition, we should analyze its goal by selecting implication analysis, and taking AND implication as example, we can establish an implication system of goal G_0 as follows:

$$G_0 \Leftarrow \begin{cases} G_{01} \Leftarrow \begin{cases} G_{011} \Leftarrow \cdots \\ \vdots \\ G_{01q_1} \Leftarrow \cdots \end{cases} \\ G_{02} \Leftarrow \cdots \\ \vdots \\ G_{0n} \Leftarrow \begin{cases} G_{0n1} \Leftarrow \cdots \\ \vdots \\ G_{0nq_n} \Leftarrow \cdots \end{cases} \end{cases}$$

If all of the most inferior goals are achieved, G_0 can be achieved. We can repeat the above steps for P_0.

The implication system of a goal can be divided into AND implications and OR implications. See also the part of the implication analysis principle in 2.1.

Moreover, we can also first conduct divergence analysis of the goal, to form a new goal through extension transformations, and if the new goal implies and is compatible with the original goal, the problem is solved.

5. Implement extension transformations or transformations' operations for the extended objects After applying extension transformations to the leaves of the correlation tree of the problem's condition, the implication system of extension transformation will be formed, taking as example the AND transformation of $L_{01}, L_{02}, L_{0m1}, \cdots, L_{0mh}$, i.e. simultaneous transformation of all leaves, we can obtain the following implication system of extension transformations:

$$\bigwedge_{i=1}^{m} {}_{L_{0i}} T_{L_0} \Leftarrow \begin{cases} T_{L_{01}} \\ T_{L_{02}} \\ \vdots \\ \bigwedge_{i=1}^{h} {}_{L_{0mi}} T_{L_{0m}} \Leftarrow \begin{cases} T_{L_{0m1}} \\ \vdots \\ T_{L_{0mh}} \end{cases} \end{cases}$$

Through conductive transformations, the compatibility of the original problem will be changed. The extension transformation or the operation formula of extension transformations that changes the problem compatibility from $K_0(P) = K(L_0) < 0$ to

$$T_K K(T_{L_0} L_0) = K'(L_0') > 0$$

is the extension strategy that solves the original incompatible problem.

As to the most inferior goals of the problem in the implication system of goals, we should first consider whether these goals can be achieved under the original condition, if they can, the problem is solved; otherwise we should conduct extensible analysis and extension transformation of the condition, and consider whether these goals can be achieved under the new condition.

6. Evaluate the superiority of the generated extension strategy by superiority evaluation method

Select one or more strategies with higher superiority as the reference strategies for decision-making. The general steps are as follows:

1) According to the opinion of experts or the decision-maker, or the actual situation, determine the evaluation characteristics: c_1, c_2, …, c_n, so as to determine the measuring indicators: (c_1,V_1) ,(c_2,V_2), … , (c_n,V_n);

2) According to the priority of measuring indicators, respectively give the weight coefficient, and the weight coefficient of the indispensable indicator, denoted as Λ; for other measuring indicators, give the value between [0,1], and set the weight coefficients as

$$\alpha_1, \alpha_2, \cdots, \alpha_{n'}, \quad n' \leq n$$

3) First sift the optional strategies by the indispensable indicator, and the strategy after sift is $s_j (j=1,2,\ldots,m)$;

4) Calculate the value of each strategy s_j about each measuring indicator: $c_i(s_j)$ $(i=1,2,\ldots,n'; j=1,2,\ldots,m)$

5) Establish different dependent functions for different measuring indicators, and calculate the dependent function value:

$$k_i[c_i(s_j)]\ ,(i=1,2,\ldots,n'; j=1,2,\ldots,m)$$

6) Calculate the standard dependent degree of each strategy about each measuring indicator:

$$k_i'[c_i(s_j)],\ (i=1,2,\ldots,n'; j=1,2,\ldots,m)$$

7) Select the calculation method of comprehensive superiority according to the different requirements of the problem, and calculate the comprehensive superiority of each strategy, such as:

$$C(s_j)=\sum_{i=1}^{n'}\alpha_i k_i'[c_i(s_j)],\ (j=1,2,\ \ldots,m)$$

$$\text{or } C(s_j)=\bigwedge_{i=1}^{n'} k_i'[c_i(s_j)]\ ,\ (j=1,2,\ \ldots,m)$$

$$\text{or } C(s_j)=\bigvee_{i=1}^{n'} k_i'[c_i(s_j)]\ ,\ (j=1,2,\ \ldots,m)$$

8) Order all strategies according to their superiority, and select the strategy with higher superiority as the reference strategy for the decision-maker.

The basic flow of the above steps is shown as Figure 4.2:

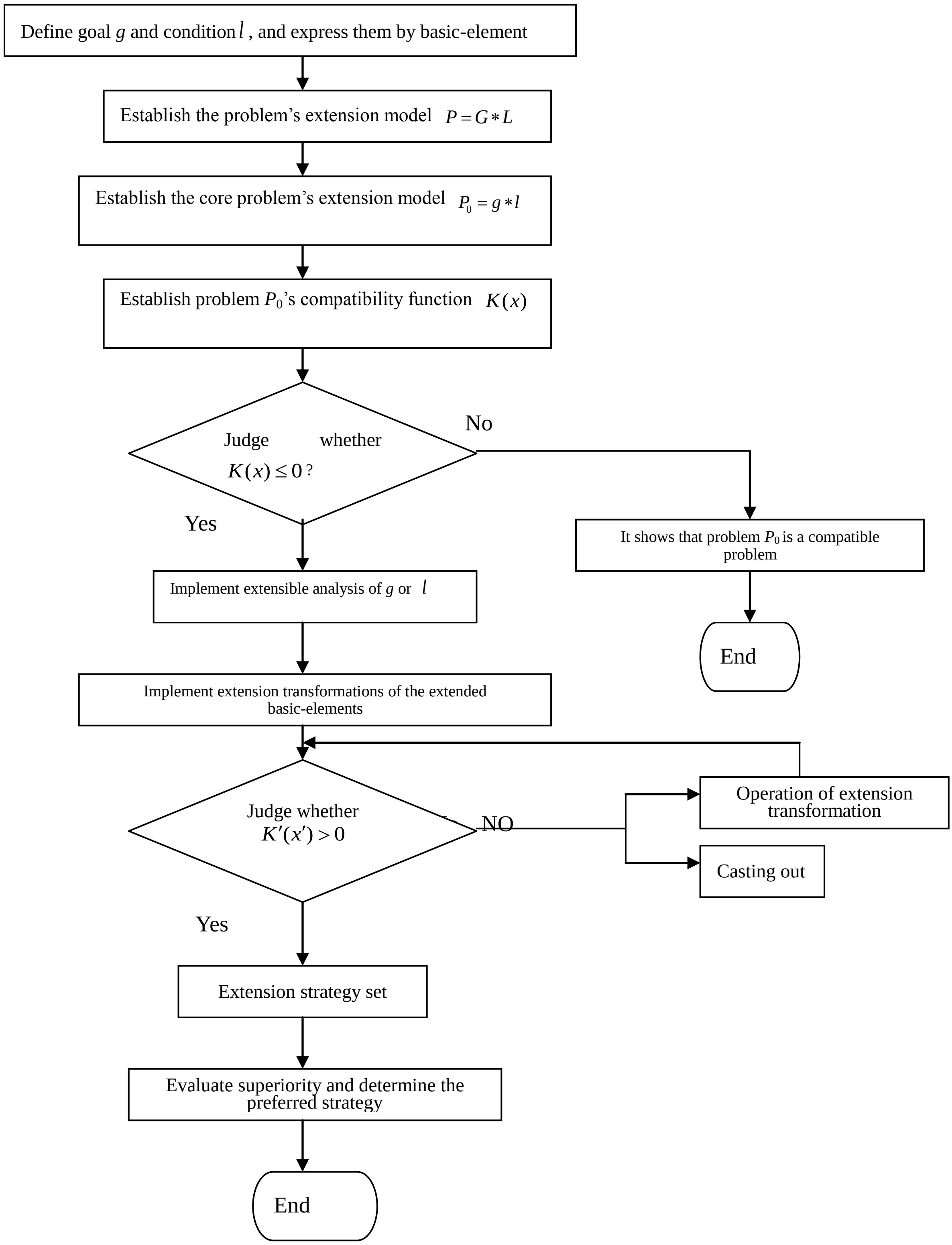


Figure 4.2 Flowchart of Solving Incompatible Problems

4.3.3 Analysis of Cases

The method to solve incompatible problems by transformation of conditions or goals is further explained in the following cases.

[**Example 4.1**] "Cao Chong weighs the elephant" is a typical case in which an incompatible problem is solved. Next we will study its solution by the extension strategy generating method.

The extension model of the problem is

$$P = G * L$$
$$= \begin{bmatrix} \text{weigh}, & \text{dominating object}, & (\text{elephant } A, \text{ weight}, \ x\text{kg}) \\ & \text{acting object}, & \text{an idea man of Cao Cao} \end{bmatrix} * \begin{bmatrix} \text{instrument}, & \text{type}, & (\text{scales } B, \text{ measure}, [0, 200]\text{kg}) \\ & \text{time}, & \text{Three Kingdoms Period} \end{bmatrix}$$

We select evaluation characteristics c_{01}=weight and c_{02}=divisibility, i.e. c_{01} and c_{02} are the characteristics of condition L about the object "elephant A" of the goal, X_{01}=[0, 200], X_{02}={1}, where the value of c_{02} indicates 1 when the weight of each divided part is under 200kg, otherwise -1. C_{0t} is the characteristic provided by the object of the goal. Denote

$$g_0 = \begin{bmatrix} \text{elephant A}, & \text{weight } c_{01}, & x\text{kg} \\ & \text{divisibility } c_{02}, & v_{02} \end{bmatrix} = \begin{bmatrix} O_0, & c_{01}, & v_{01} \\ & c_{02}, & v_{02} \end{bmatrix},$$

$$l_0 = (\text{scales B}, \ \ \text{measure } c_{0t}, \ \ [0, \ 200]\text{kg}),$$

Then the extension model of the core problem of problem P is

$$P_0 = g_0 * l_0$$
$$= \begin{bmatrix} \text{elephant } A, & \text{weight}, & x\text{kg} \\ & \text{divisibility}, & -1 \end{bmatrix} * \begin{bmatrix} \text{scales } B, & \text{measure}, & [0, 200]\text{kg} \end{bmatrix}$$

Establish the extension set with X_{01} and X_{02} as positive fields

$$\tilde{A}(T)=\{ (g, y, y') \mid g \in W, y = k_1(x_1) \wedge k_2(x_2) \in \boldsymbol{I};$$
$$T_g g \in T_W W, y' = T_K K(T_g g) \in \boldsymbol{I} \}$$

wherein

$$k_1(x_1) = \frac{200 - x_1}{200}, \quad k_2(x_2) = \begin{cases} -1, & \text{when } x_2 \text{ cannot be divided into parts with each under 200kg} \\ 1, & \text{when } x_2 \text{ can be divided into parts with each under 200kg} \end{cases}.$$

It's obvious the compatibility degree of problem P is

$$K(P) = k_1(v_{01}) \wedge k_2(v_{02}) = \frac{200 - v_{01}}{200} \wedge (-1) < 0, \text{ when } v_{01} >> 200$$

So problem P is an incompatible problem. In other words, this problem is an incompatible problem to the idea man of Cao Cao.

It's obvious that this problem cannot be solved directly by transformation of condition; in other words, at that time, all scales were not capable of weighing an elephant. Hence, the transformation of goals must be taken into consideration. It's required that the original goal must be achieved when the goal after transformation is achieved, i.e. we should meet

$$g = \begin{bmatrix} O, & \text{weight } c_{01}, & x\text{kg} \\ & \text{divisibility } c_{02}, & 1 \end{bmatrix} = \begin{bmatrix} O, & c_{01}, & v_{01} \\ & c_{02}, & 1 \end{bmatrix},$$
$$\text{and } g \Rightarrow g_0$$

As to this problem, according to the divergence analysis method (multiple matters with one characteristic):

$$g_0 \dashv \left\{ g_1 = \begin{bmatrix} \text{stones heap } A_1, & c_{01}, & x\text{kg} \\ & c_{02}, & 1 \end{bmatrix}, g_2 = \begin{bmatrix} \text{sand heap } A_2, & c_{01}, & x\text{kg} \\ & c_{02}, & 1 \end{bmatrix}, \; g_2 = \begin{bmatrix} \text{wood heap } A_3, & c_{01}, & x\text{kg} \\ & c_{02}, & 1 \end{bmatrix} \cdots, \right\}$$

According to the divisibility: $g_i / \{g_{i1}, \; g_{i2}, \ldots, \; g_{in_i}\}, \; i = 1, 2, 3, \cdots$, for example

$$g_{1j} = \begin{bmatrix} \text{stone } A_{1j}, & c_{01}, & x_j\text{kg} \\ & c_{02}, & 1 \end{bmatrix}, \quad x_j << 200\text{kg}, \quad j = 1, 2, \cdots, n_1$$

and then according to the actual situation and convenience at that time, select anyone among them as the goal of implication g_0.

The next problem is, in the case that x of g_0 was unknown and could not be known by scales measurements at that time, how to measure the equivalence of g_i and g_0? This means the goal G “to weigh the elephant” is transformed to the goal G_1 to find a “measuring instrument” to measure the equivalent of g_i and g_0 (the goal of Cao Chong), it’s obvious

$$G \Leftarrow G_1, G_1 = [\text{measure}, \quad \text{dominating object}, \quad g_0 \Leftrightarrow g_i]$$

According to correlation analysis: on land,

$$[O, \quad \text{weight}, \quad x] \sim [O, \quad \text{volume}, \quad z], z = f(x)$$

while in water, we have

$$[O, \quad \text{weight}, \quad x] \sim [O, \quad \text{buoyance}, \quad z_1] \sim [\text{load carrier}, \quad \text{draught}, \quad z_2],$$

and then conduct implication analysis of goals according to existing knowledge, we have

$$G_1 \Leftarrow G_{11} \vee G_{12}$$

wherein

$$G_{11} = \begin{bmatrix} \text{measure}, & \text{dominating object}, & g_0 \Leftrightarrow g_i \\ & \text{tool}, & \text{lever} \vee \text{forked branch} \vee \cdots \\ & \text{location}, & \text{on land} \end{bmatrix}, G_{12} = \begin{bmatrix} \text{measure}, & \text{dominating object}, & g_0 \Leftrightarrow g_i \\ & \text{tool}, & \text{boat} \vee \text{raft} \vee \cdots \\ & \text{location}, & \text{in water} \end{bmatrix}$$

i.e. the lever and boat, etc. can be used to measure the equivalent of g_i and g_0. To use a lever on land, we need a very large container to load the elephant at one end and the object(s) with weight equivalent to the elephant at the other end, which can be hardly realized. To use the boat in the water, according to the knowledge that “the objects with the same boat draught have equivalent weight”, we can lead the elephant onto the boat and scribe the draught and then replace the elephant with other objects until the same draught is reached. Thus we realize the goal G_{12}, and also realize G_1. It’s obvious that the boat is the most convenient “measuring instrument”.

We make $T_i g_0 = g_i \; (i = 1,2,3)$, and then make $T_i' g_i = \{g_{i1}, \; g_{i2}, \ldots, \; g_{in}\}$, wherein

$$T_i = \begin{bmatrix} \text{substitution}, \text{dominating object}, & g_0 \\ \text{receiving object}, & g_i \\ \text{tool}, \text{boat} & \end{bmatrix},$$

$$T_i' = \begin{bmatrix} \text{decomposition}, & \text{dominating object}, & g_i \\ & \text{receiving object}, & \{g_{i1}, g_{i2}, ..., g_{in}\} \\ & \text{tool}, & \text{labor} \end{bmatrix}$$

$$g_{ij} = \begin{bmatrix} A_{ij}, & c_{01}, & [0, x_{ij}] \\ & c_{02}, & 1 \end{bmatrix},$$

and $x_{i1} + x_{i2} + \cdots + x_{in} = x,\ \ x_{ij} < 200,\ \ (i = 1,2,3,\ \ j = 1,2,\cdots,n)$, then

$$K(T_i'T_i g_0) = \bigwedge_{j=1}^{n} K(T_i' g_i) = \bigwedge_{j=1}^{n} K(x_{ij}) = \bigwedge_{j=1}^{n} [K_1(x_{ij}) \wedge K_2(x_{ij})] = \bigwedge_{j=1}^{n} (\frac{200 - x_{ij}}{200} \wedge 1) > 0$$

i.e. we make transformation

$T_i' T_i$ ={substitute the elephant by divisible object A_i with equivalent weight on the boat, and then decompose A_i into measurable objects A_{ij}}, to transform the incompatible problem to a compatible one.

This is the method used by Cao Chong who found the equivalent goal by obtaining the boat draught equivalent to the boat draught loaded with the elephant, and measured the elephant's weight by "boat$\oplus$ small scales".

This case concerns substitution transformation of the object in the goal matter-element. In some cases, the incompatible problem may be transformed to a compatible problem by changes of characteristic or measure. For the transformation method, see also 3.2 of this book. For another example, to move a cabinet 3m high into the door 2m high, the cabinet should be "pulled down", i.e. this problem with the contradiction between the cabinet height and door height can be solved by utilizing another characteristic of the cabinet – "width".

[**Example 4.2**] An enterprise E plans to construct a workshop W at certain location, with an estimated cost of <4.5, 5> million yuan. But the enterprise fund available for constructing the workshop is less than 1 million yuan. Supposing the goal to construct the workshop cannot be changed, this contradictory problem can be solved by the method to transform the condition only.

The extension model of the problem is:

$$P = G * L$$

$$= \begin{bmatrix} \text{construct}, & \text{dominating object}, & \text{workshop } W \\ & \text{acting object}, & \text{enterprise } E \\ & \text{cost}, & <4.5,5> \text{ million Yuan} \end{bmatrix} * \begin{bmatrix} \text{enterprise } E, & \text{available fund}, & \text{1 million Yuan} \\ & \text{staff amount}, & 1000 \\ & \text{project type}, & \text{hi-tech} \\ & \text{credit worthiness}, & 5 \end{bmatrix}$$

The extension model of the problem's core problem is:

$$\begin{aligned} P_0 &= g_0 * l_0 \\ &= (\text{workshop } W, \text{fund needed}, <4.5,5> \text{ million Yuan}) * (\text{enterprise } E, \text{funding}, \text{1 million Yuan}) \\ &= (W,\ c_{0s}, <4.5,5> \text{ million Yuan}) * (B,\ c_{0t},\ \text{1 million Yuan}) \end{aligned}$$

With X_0=<4.5, 500> as a satisfying field (standard positive field), X=<4.4, 6.5> as an acceptable field (positive field), and optimal point x_0=4.75, we establish elementary dependent function as compatibility function based on formula (3) in section 2.7 of the book:

$$K(l)=k(x)=\frac{\rho(x,X)}{D(x,X_0,X)}$$

According to the formula (1) of extension distance and the formula (2) of place value in 2.7:

$$\rho(x\ ,X)=\left|x\ -\frac{440+650}{2}\right|-\frac{650-440}{2}=\left|x\ -545\right|-105$$

$$\rho(x\ ,X_0)=\left|x\ -\frac{450+500}{2}\right|-\frac{500-450}{2}=\left|x\ -475\right|-25$$

$$D(x,X_0,X)=\rho(x,X)-\rho(x,X_0)=\left|x-545\right|-\left|x-475\right|-80$$

Therefore,

$$K(l)=k(x)=\frac{\rho(x,X)}{D(x,X_0,X)}=\frac{\left|x-545\right|-105}{\left|x-545\right|-\left|x-475\right|-80}$$

Then when $x=1$ million yuan, $K(l_0)=k(1)=\frac{4.45-1.05}{-0.1}=-34<0$, i.e. the problem $P=G*L$ is an incompatible problem.

As the workshop W must be constructed, this contradictory problem must be solved by transformation of condition l_0. The condition of this problem is a real resource condition, so we should first conduct conjugate analysis of the enterprise resources, to find the resource advantages of the enterprise.

According to divergence analysis:

$$l_0 \dashv \begin{cases} (\text{bank}O_1,\ \ c_{0t},v_1) \\ (\text{staff}O_2,\ \ c_{0t},v_2) \\ (\text{risk company}O_3,\ \ c_{0t},v_3) \\ \cdots \end{cases}$$

After resources analysis, the advantageous resource of the enterprise is a soft resource – relations resource, i.e. the enterprise has good relations with banks and good credit worthiness in one bank, from which loan at lower interest can be obtained. In addition, the enterprise has been just transformed to a shareholding system, and the enterprise also has good cohesiveness and centripetal force, so its staff may buy shares in the form of capital-raising. Third, the enterprise also enjoys imaginary resource advantages – projects with hi-tech content, which is the eventual purpose of the workshop to be constructed, therefore, this project can be used to attract risk investment or cooperation in other forms.

It can be seen that we can conduct transformation of at least the following three conditions:

(1) $T_1l_0=(E\oplus O_1,\ \ c_{0t},\ \ \text{5 million Yuan})=l_1'$, $K(l_1')=k(5)=1>0$

T_1 is 4 million yuan loan from bank O_1, which is combined with the enterprise fund.

(2) $T_2l_0=(E\oplus O_2,\ \ c_{0t},\ \ \text{3million Yuan})=l_2'$, and $K(l_2')=k(3)=-14<0$

T_2 is shares buying and capital raising by internal staff O_2, to raise capital of 2 million yuan, which is combined with the enterprise fund.

(3) $T_3 l_0 =$（$E \oplus O_3$, c_{0t},4.2 million Yuan）$= l_3'$, and $K(l_3') = k(4.2) = -2 < 0$

T_3 is an investment by risk company O_3 attracted by the hi-tech project, to raise capital of 3.2 million yuan, which is combined with the enterprise funding.

Among the above three transformations, only T_1 can let $k(x) \geq 0,\ (i = 1,\ 2,\ 3)$, i.e. T_1 can transform the incompatible problem to a compatible one, while T_2 and T_3 cannot. But

$$Tl_0 = (E \oplus O_2 \oplus O_3,\ c_{0t},\ \text{6.2million Yan}) = l' \ ,K(l') = k(6.2) = 0.2 > 0$$

That is, let $T = T_2 \wedge T_3$, this incompatible problem can also be solved. T implies that it can be solved by conducting transformations of both shares buying and capital raising by internal staff and attraction of risk investment (i.e. AND operation of transformation).

The above transformations T_1 and T form two different strategies for solving the incompatible problem, and the preferred strategy will be eventually selected by evaluation according to the actual situation of the enterprise, such as bank interest rates, capacity for loan repayments, and other measuring conditions, which are omitted.

4.4 Antithetical Problem Solving Method

——Transforming Bridge Method

The antithetical problems are usually solved by the following three methods: (1) “either-or” conflicting method. Such as “confirming one party while negating the other”, “taking my advice” or “taking your advice” etc., which is simple and direct, but easy to cause new problems. (2) Balance methods of “both A and B”, also referred to as the compromising method. Such as “one takes thirty percent and the other takes seventy percent”, by which both contradictory parties obtain partial benefit through bargaining, and the contradiction is compromised at the eclectic point, this method is usually realized through negotiation. (3) Transforming bridge method “with reciprocal indifference and proper place”. This is an artful method to solve contradictory problems.

According to the concept of problem coexistence, to transform antithetical problems to coexistent problems, the key is to find the transformation, to change the problems coexistence from being less than 0 to be more than 0.

The transforming bridge method is a method to connect or separate the two antithetical parties and transform them to be coexistent through setting the transforming bridge, by using the thinking of “reciprocal indifference and proper place”. By the transforming bridge method, the antithetical problem can be transformed to a coexistent problem.

The essence of the transforming bridge is to let the antithetical parties “have reciprocal indifference and proper place”, i.e. to let them be satisfied at different locations (or about different characteristics).

For example, the traffic keeps to the left in Hong Kong Special Administrative Region and keeps to the right in Mainland China, and the Huanggang Bridge in Shenzhen is a transforming bridge to connect these two antithetical traffic systems into a coexistent system. “One Country, Two Systems” is the transforming bridge to connect the economic systems of Hong Kong and Mainland China that have different economic institutions.

According to the definition of antithetical problems and the establishing method of antithetical problem’s extension model given in 4.1, this section gives the method to solve antithetical problems – transforming bridge method.

For easy explanation, all antithetical problems referred to below are core problems (for some simple problems, their original problems may be the same to their core problems), and are expressed by uppercases; the original problem is expressed by uppercase and the core problem is expressed by lowercase only in the case of particular distinction.

4.4.1 Concept of Transforming Bridge

Given antithetical problems $P=(G_1 \wedge G_2)*L$, $(G_1 \wedge G_2)\uparrow L$, if there is transformation T=(T_{G_1}, T_{G_2}, T_L), to let

$$(T_{G_1}G_1 \wedge T_{G_2}G_2)\downarrow T_L L$$

then we call T solution transformation of problem P, which lets G_1 and G_2 coexistent.

The transforming object of solution transformation is an indispensable component in antithesis–coexistence transformation, and for its transforming role in the process of solving antithetical problems, we visually call it a transforming bridge, denoted as $B(G_1, G_2)$.

4.4.2 Structure of Transforming Bridge

A transforming bridge is generally composed of the transforming part *Z* and transforming passage *J*, denoted by

$B(G_1, G_2) = Z * J$

In some cases, the transforming passage may not be necessary; here, the transforming part is the transforming bridge.

1. Transforming parts

There are two types of transforming parts: one is connective transforming parts and the other is separative transforming parts.

(1) Connective Transforming Parts

As to two antithetical systems S_1 and S_2, we make combination transformation *T*, to connect S_1 and S_2 into a part *Z* of a large system *S*, which is called the connective transforming part of S_1 and S_2, denoted by

$$T(S_1, S_2) = S_1 \otimes Z \otimes S_2 = S$$

The Huanggang Bridge in Shenzhen is the connective transforming part that connects the two antithetical traffic systems.

The basic-elements composed of the connective transforming part are called connective transforming basic-elements, including the connective transforming basic-elements of objects and the connective transforming basic-elements of measure.

a) If *Z* is a connective transforming object, the connective transforming basic-elements of objects can be expressed by

$$B_1 = (S_1 \otimes Z, c, v_1), B_2 = (Z \otimes S_2, c, v_2)$$

b) If *Z* is a connective transforming measure, the connective transforming basic-element of measure can be expressed by

$$B_1 = (O_1, c, v_1 \oplus Z) = (O_1, c, v_1'), \quad B_2 = (O_2, c, Z \oplus v_2) = (O_2, c, v_2')$$

wherein, when the measure is a quantitative measure, the “$\oplus$” is the same to “+” in mathematics; when the measure is not a quantitative measure, the “$\oplus$” is different from the “+” in mathematics, indicating a “combination” of the two measures.

(2) Separative Transforming Parts

As to an antithetical problem in a large system, we make decomposition transformation *T*, and the part *Z* that separates *S* into S_1 and S_2 to solve the antithetical problem is called the separative transforming part of *S*, denoted by

$$TS = S_1 \mid Z \mid S_2$$

The problem with having a “wolf and chicken in the same cage” is solved by adding an iron fence *Z* in the cage *S* to solve the contradictory problem that the wolf may eat the chicken, here, *Z* is the separative transforming part of *S*.

The basic-element composed of separative transforming parts is called separative transforming basic-elements, including the separative transforming basic-elements of objects and the separative transforming basic-elements of measures.

a) If *Z* is a separative transforming object, the separative transforming basic-element of objects can be expressed by

$$B_1 = (S_1 Z, c, v_1), B_2 = (Z S_2, c, v_2)$$

b) If *Z* is a separative transforming measure, with the original measure of *v*, the separative transforming basic-element of measure can be expressed by

$$B_1 = (O_1, c, v_1 Z) = (O_1, c, v_1'), \quad B_2 = (O_2, c, Z v_2) = (O_2, c, v_2')$$

wherein, “$v_1 Z$” and “$Z v_2$” indicates the two measures decomposed from *v*, and we have $v_1 Z \oplus Z v_1 = v$. When the measure is a quantitative measure, its decomposition is the same to that in mathematics.

2. Transforming passages

To transform antithetical problems to coexistence, some are transformed to coexistence by directly constructing the transforming part, but some have their transforming part constructed after certain transformations. The process that the basic-element is transformed into the transforming part is called a transforming passage. Before introducing the concept of a transforming passage, we must first introduce the concepts of transforming goals and transforming conditions.

(1) Transforming Goals

As to given antithetical problem $P = (G_1 \wedge G_2) * L$, $(G_1 \wedge G_2) \uparrow L$, if there are basic-elements G_1' and G_2', $G_1' \Rightarrow G_1$, $G_2' \Rightarrow G_2$, to let $(G_1' \wedge G_2') \downarrow L$, then we call (G_1', G_2') the transforming goal.

(2) Transforming Conditions

As to given antithetical problem $P = (G_1 \wedge G_2) * L$, $(G_1 \wedge G_2) \uparrow L$, if there is certain transformation *T* and basic-element L', $L' = TL$, to let $(G_1 \wedge G_2) \downarrow L'$, we call L' the transforming condition.

It can be seen from the above two concepts that the passage to change the goal is constructed by using the implicative relation of basic-elements, and the passage of restriction or to transform the condition is constructed by using the transformation of basic-elements. The former is called implying passage and the latter is called transforming passage.

When solving antithetical problems, the passage adopted to achieve the transforming goal is implying passages:

$$\underbrace{G_1 \Leftarrow G_{11} \Leftarrow G_{12} \Leftarrow \cdots \Leftarrow G_{1n}}_{\text{Implying passage}} \underbrace{(\quad Z \quad)}_{\text{Transforming part}} \underbrace{G_{2m} \Rightarrow G_{2,m-1} \Rightarrow \cdots \Rightarrow G_{21} \Rightarrow G_2}_{\text{Implying passage}}$$

and the passage adopted to achieve the transforming condition is a transforming passage:

$(T_m T_{m-1} \cdots T_1)L = L'(Z)$

3. Steps and basic flows to transform an antithetical problem to a coexistent problem

According to the constructing method of the transforming bridge, the basic steps to transform antithesis to coexistence are as follows:

(1) Implement transformation T_L of condition L, to form the transforming part or transforming passage. T_L may be the transformation of the object or measure in the condition, which respectively forms separative transforming objects or transforming measures; T_L may also be a series of transformations of condition basic-elements, to form transforming passage. Let $T_L L = L'$, if $K_{L'}(G_1, G_2) > 0$, the antithetical problem is transformed to a coexistent one.

(2) Implement transformations (T_{G_1}, T_{G_2}) of goals (G_1, G_2), to form the transforming part or implying passage. (T_{G_1}, T_{G_2}) may be the transformations of objects or measures in the goals, which respectively form the connective transforming objects or transforming measures; it may also implement directly implication analysis for goals (G_1, G_2), to form implying passage. Let $T_{G_1} G_1 = G_1'$, $T_{G_2} G_2 = G_2'$, and $G_1' \Rightarrow G_1$, $G_2' \Rightarrow G_2$, if $K_L(G_1', G_2') > 0$, the antithetical problem is transformed to a coexistent one.

(3) Simultaneously implement transformations of condition L and goals (G_1, G_2), to form transforming parts or transforming passage/implying passages. Let $T_L L = L'$, $T_{G_1} G_1 = G_1'$, $T_{G_2} G_2 = G_2'$, and $G_1' \Rightarrow G_1$, $G_2' \Rightarrow G_2$, if $K_{L'}(G_1', G_2') > 0$, the antithetical problem is transformed to a coexistent one.

In the above process, if the transformation of condition L forms transforming passage, then $T_L = T_{1L} T_{2L} \cdots T_{sL}$ is the operation result of a series of transformations, which transform L to L'; if the transformation of goal (G_1, G_2) forms implying passage, then $G_1' \Rightarrow G_{11} \Rightarrow G_{12} \Rightarrow \cdots \Rightarrow G_{1m} \Rightarrow G_1$, $G_2' \Rightarrow G_{21} \Rightarrow G_{22} \Rightarrow \cdots \Rightarrow G_{1n} \Rightarrow G_2$, i.e. G_1' is the most inferior goal of G_1, and G_2' is the most inferior goal of G_2.

The basic flow to transform antithetical problem to coexistent problem is shown as the Figure 4.3.

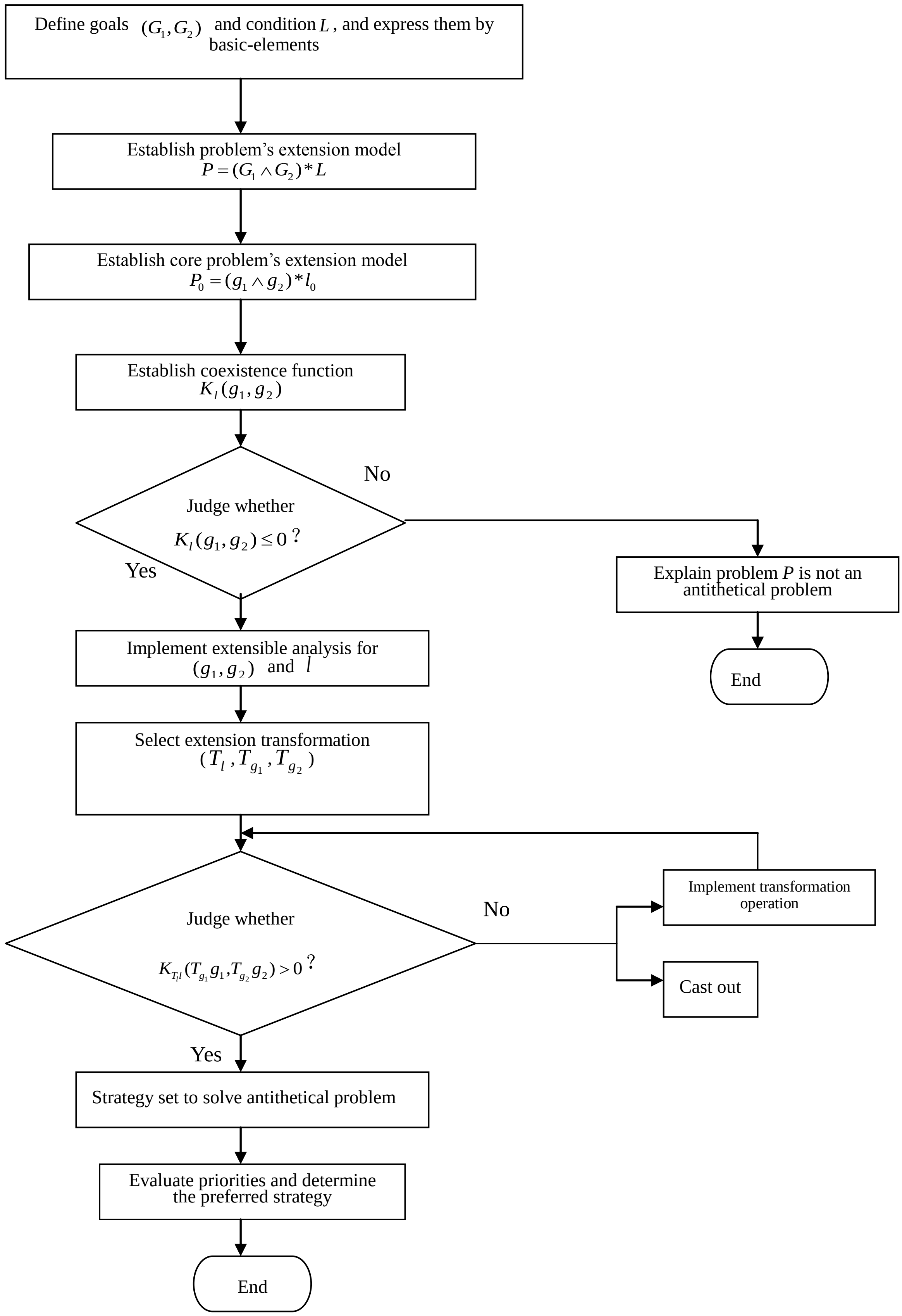


Figure 4.3 Flowchart to Solve Antithetical Problem

4.4.3 Method to Tackle Antithetical Problems by Transforming Bridges

It can be seen from the concept of transforming bridges that the transforming bridge is composed of transforming parts and transforming passages, and in constructing the transforming bridge to tackle antithetical problems, the key is the way to construct the transforming part and transforming passages.

1. Construction of transforming parts

The constructing process of transforming parts of antithetical problem can be boiled down to the constructing process of transforming key elements. In terms of basic-elements, the transforming key elements may be transforming object or transforming measures. In general, once the transforming element is found, the antithetical problem can be transformed to a coexistent problem.

(1) Object Serves as the Transforming Part – Separative Transforming Object and Connective Transforming Object

The method to tackle antithetical problems by using objects as transforming parts is a common method. The “boiler” allows the “antithesis of water and fire” to coexist; when it’s raining, an umbrella can protect us from getting drenched; the animal cage in the zoo, and the caged bus for visitors in a safari park, are both transforming phenomena for coexistence between humans and animals.

These transforming objects are separative transforming objects. A separative transforming object is generally a decomposition transformation of the object involved in the condition. The constructing steps are shown as Figure 4.4.

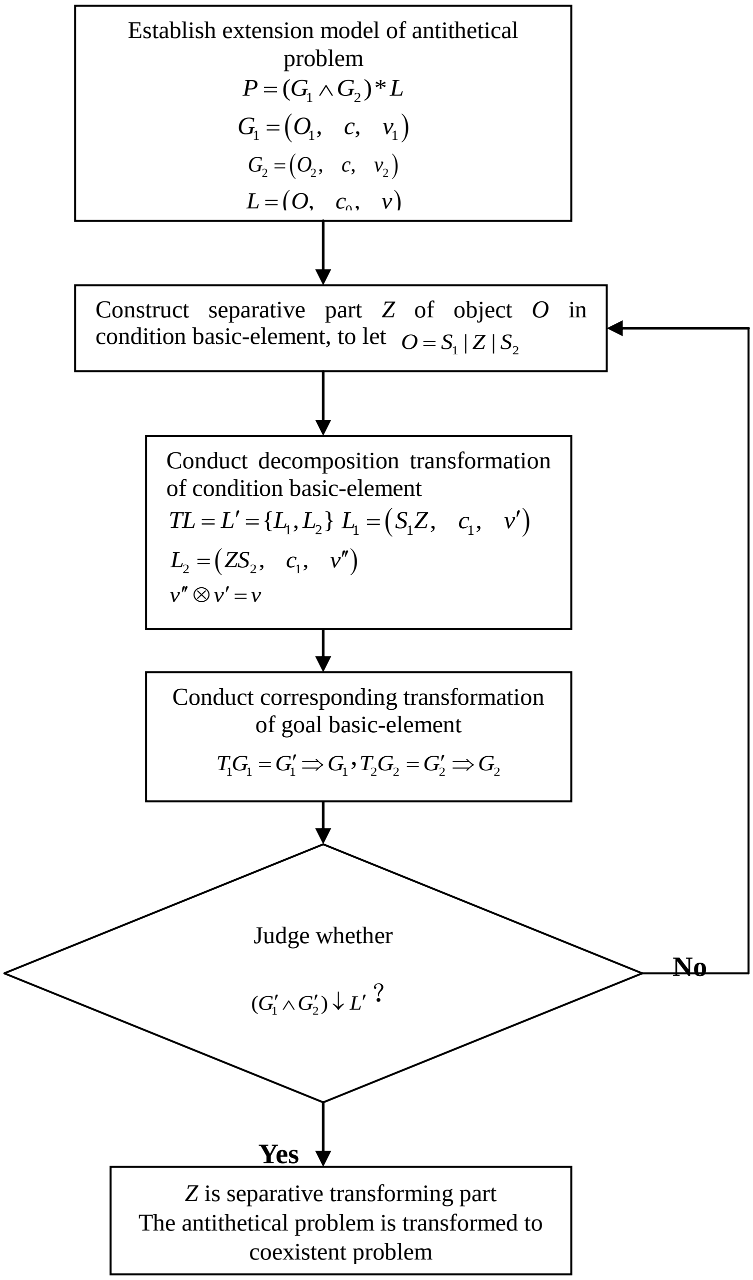


Figure 4.4 Flowcharts to Construct Separative Transforming Part

To solve the problem of antithetical opinions among a decision-making group (such as a team or a couple), we usually transform antithetical problem to coexistent problems by adopting the method of setting the separative transforming object. For example, regarding the “dietary” problem, there are usually many antithetical opinions: some like hot peppers, while some do not, but this problem can be easily solved in general, for example, we may cook some dishes with hot peppers and some without hot peppers, or we may cook one dish but take a part of the dish out before putting the hot peppers in, however, when two people eat in one hotpot, they must first decide the “soup base”. It seems very difficult to meet the antithetical requirements of the two people. But the restaurant adopts the method of transforming the “pot” (i.e. the matter in condition) – adds one separator in the hot, thus the “double-flavored hotpot” is born. Of course, nowadays, some restaurants provide small hotpots for each customer, so each person may select any soup base, which is also a method to solve the problem with the antithesis between multiple things, and this design thinking is also to decompose and separate the object (i.e. decompose a large hotpot into multiple small hotpots).

The connective transforming object is generally set between the goal's objects. The basic steps are shown as Figure 4.5.

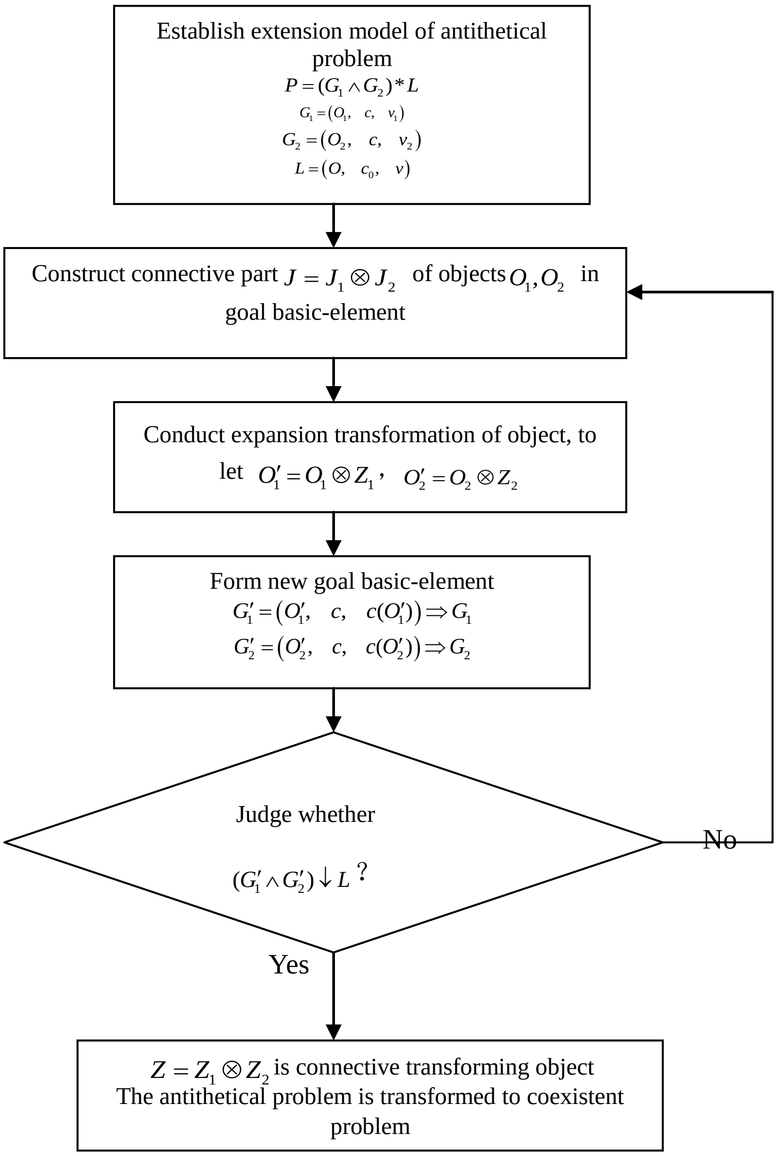


Figure 4.5 Flowchart to Construct Connective Transforming Parts

[**Example 4.3**] The design of transforming bridges for the problem of having a "wolf and chicken in the same cage".

To put a wolf and a chicken in the same cage while preventing the wolf from eating the chicken, obviously, it's an antithetical problem. Suppose

$$G_1=\begin{pmatrix} \text{wolf } O_1, & \text{habit}, & \text{meat-eating} \\ & \text{location}, & \text{in cage } O \end{pmatrix}=\begin{pmatrix} O_1, & c_1, & v_{11} \\ & c_2, & v_{12} \end{pmatrix}$$

$$G_2=\begin{pmatrix} \text{chicken } O_2, & \text{habit}, & \text{mild} \\ & \text{location}, & \text{in cage } O \end{pmatrix}=\begin{pmatrix} O_2, & c_1, & v_{21} \\ & c_2, & v_{22} \end{pmatrix}$$

$$L=(\text{cage } O,\ \text{capacity},\ a\text{m}^3)=(O,\ \ c,\ \ v)$$

then $(G_1 \wedge G_2) \uparrow L$.

We make separative part Z of condition object O, to let $O = S_1 | Z | S_2$, and then we have decomposition transformation of condition basic-elements

$$TL = L' = \{L_1, L_2\}$$

$$L_1 = (S_1 Z,\quad c,\quad v_1),\ L_2 = (ZS_2,\quad c,\quad v_2),\ v_1 \oplus v_2 = v$$

We make the corresponding transformation of goals a basic-element

$$T_1 G_1 = G_1' = \begin{pmatrix} O_1, & c_1, & v_{11} \\ & c_2, & S_1 Z \end{pmatrix} = \begin{pmatrix} \text{wolf } O_1, & \text{habit}, & \text{meat-eating} \\ & \text{location}, & \text{in } S_1 Z \end{pmatrix}, \text{ and } \ G_1' \Rightarrow G_1$$

$$T_2 G_2 = G_2' = \begin{pmatrix} O_2, & c_1, & v_{21} \\ & c_2, & ZS_2 \end{pmatrix} = \begin{pmatrix} \text{chicken } O_2, & \text{habit}, & \text{mild} \\ & \text{location}, & \text{in } ZS_2 \end{pmatrix}, \text{ and } \ G_2' \Rightarrow G_2$$

then $(G_1' \wedge G_2') \downarrow L'$, where $O = S_1 | Z | S_2$ is separative transforming matter.

(2) Measure Serves as a Transforming Part – Separative Transforming Measures and Connective Transforming Measures

That measure serves as a transforming part means that the decomposability and combinability of measures are utilized to construct the transforming parts by the corresponding basic-elements. For example, for the artificial satellite to transmit multiple different parameters to the earth, but it’s installed with only one transmitter to reduce its weight, “time division multiplexing (TDM)” is an effective method to solve this antithetical problem, i.e. it can transmit different parameters at different time intervals. This is also the thinking to fully utilize the resources. For another example, the traffic in different times and the one-way/two-way traffic in different times in traffic control adopt this thinking as well. In order to relieve the lift pressure at on/off duty peaks in highrise office buildings, the methods to separate the on/off duty times or to restrict the through-lift to certain floors are using the measure as a transforming part.

2. Construction of transforming passages

As to antithetical problem $P = (G_1 \wedge G_2) * L$, where $G_1 = (O_1,\quad c_1,\quad v_1)$, $G_2 = (O_2,\quad c_2,\quad v_2)$, $L = (O,\quad c,\quad v)$.

If it cannot be transformed to a coexistent problem by directly constructing the transforming part, we should construct the transforming passage. We should use implying passages for the goal and transforming passages for the condition. Some antithetical problems can be transformed to coexistent problems by using one of them, but some by using them both.

Actually, in constructing the transforming part, the transformation of condition is a particular transforming passage, and it’s called a transforming passage after more than two transformations in general, while the above-mentioned transformation of condition is called transforming condition.

If the antithetical problem cannot be transformed to a coexistent one by the transforming passage, we should conduct implication analysis of goal basic-elements G_1 and G_2, to find the respective most inferior basic-elements G_{1n} and G_{2m} of G_1 and G_2, i.e.

$$G_1 \Leftarrow G_{11} \Leftarrow G_{12} \Leftarrow \cdots \Leftarrow G_{1n}$$

$$G_2 \Leftarrow G_{21} \Leftarrow G_{22} \Leftarrow \cdots \Leftarrow G_{2m}$$

If $(G_{1n} \wedge G_{2m}) \downarrow L(\text{or } L')$, the antithetical problem can be transformed to a coexistent one.

[Example 4.4] The owner of a mountain villa could not decide whether to construct a golf training course or an artificial lake for angling on a vacant field of 20000 m^2. This problem is obviously an antithetical problem, with goal basic-elements

$$G_1 = \begin{bmatrix} \text{construct}, & \text{dominating object}, & \text{golf training course} \\ & \text{location}, & D \end{bmatrix} = \begin{bmatrix} O_a, & c_{a1}, & v_{a1} \\ & c_{a2}, & D \end{bmatrix}$$

$$G_2 = \begin{bmatrix} \text{construct}, & \text{dominating object}, & \text{artificial lake} \\ & \text{location}, & D \end{bmatrix} = \begin{bmatrix} O_a, & c_{a1}, & v_{a2} \\ & c_{a2}, & D \end{bmatrix}$$

and condition basic-element $L=(D$, area, 20000 m$^2)$, then the problem's extension model is $P=(G_1 \wedge G_2) * L$.

According to a general standard, the area of a golf training course should be at least 20000m^2, while the area of an artificial lake is never less, so $(G_1 \wedge G_2) \uparrow L$.

According to implication analysis:

G_1

$\Uparrow \; l_1$

and

$$G_{11} = \begin{bmatrix} O_a, & c_{a1}, & \text{tee} \\ & c_{a2}, & D_1 \end{bmatrix} \quad G_{12} = \begin{bmatrix} O_a, & c_{a1}, & \text{green} \\ & c_{a2}, & D_2 \end{bmatrix}$$

G_2

$\Uparrow \; l_2$

and

$$G_{21} = \begin{bmatrix} O_a, & c_{a1}, & \text{lakeshore} \\ & c_{a2}, & D_1' \end{bmatrix} \quad G_{22} = \begin{bmatrix} O_a, & c_{a1}, & \text{lake water} \\ & c_{a2}, & D_2' \end{bmatrix}$$

i.e. $G_1 \Leftarrow (l_1)\{G_{11}, \; G_{12}\}$, $G_2 \Leftarrow (l_2)\{G_{21}, \; G_{22}\}$, where l_1: $D_1 \otimes D_2 = D$, l_2: $D_1' \otimes D_2' = D$.

We make transformation T: $TL = L' = \{L_1, \; L_2\}$, wherein, $L_1 = \left(D_1', \quad \text{area}, \quad a_1\text{m}^2\right)$, $L_2 = \left(D_2', \quad \text{area}, \quad a_2\text{m}^2\right)$, and $a_1 \otimes a_2 = 20000\text{m}^2$, then

$$(G_{11} \wedge G_{21}) \downarrow L_1, \quad (G_{12} \wedge G_{22}) \downarrow L_2$$

i.e. the tee can be constructed on the lakeshore with area $a_1\text{m}^2$, and the green can be constructed on the lake surface with area $a_2\text{m}^2$, i.e. the golf ball can be shot into the lake water, thus, both golf training courses and artificial lakes can be constructed on the same field. This is an excellent example of full utilization of land resources.

In this case, the lake surface plays the transforming role and constitutes the connective transforming part, to transform the antithetical problem to a coexistent one.

4.5 Preliminary Study on Intelligent Processing of Contradictory Problems

In engineering technology and economic management, people have to tackle assorted contradictory problems. In the past, these contradictory problems were solved relying on the wisdom and ingenuity of the engineering technicians, managers and decision makers. However, with the scientific and technological development as well as economic and social progress, we have increasingly complicated contradictory problems we come across because there are more and more parameters to consider, involving increasingly extensive systems and complicated relations between systems. The solution to one contradictory problem will cause new contradictory problems, and the treatment of one system contradictory problem will cause new contradictory problems in other systems. Therefore, the increasingly complicated contradictory problems cannot be solved only relying on the wisdom and ingenuity of people. The study on the generation and evaluation of the strategies to solve them by computer is an important frontier and fundamental study featured by intense explorations, and the deepening of this study will inevitably lead to the development of intelligent systems to solve contradictory problems in various professional fields, which will play an important role in the scientific and technological development as well as economic and social progress, as the subject that is inevitably discussed by humans facing the current development of science and technology.

With the scientific progress, full utilization of intelligent tools will become an important task for national economic modernization in various fields. Therefore, the creation of intelligent problem processing systems is important work in contemporary science and technology. The key points of this S&T level are the ways a computer processes the acquired information into knowledge, and the way the computer utilizes the information and knowledge to generate strategy to process the contradictory problems. The study on the theory and method of intelligent contradictory problem processing is an important subject in intelligence science.

In terms of the development of computer technology, the newly born computer replaced our heavy work of numerical calculation by its high speed operation; the subsequent incoming data allowed us to express information by computer and developed the computer searching function, to help our data processing; the application of knowledge engineering helped us reason and match the complex data, leading to the appearance of expert systems and decision support systems. Facing the current development of computer technology, the study on the generation of contradictory problem processing strategy has become a matter of course. The development process of computer technology can be briefed as the following figure:

Numbers →	Data →	Knowledge →	Strategy
(Measure)	(Basic-element)	(Relational expression of basic-elements)	(Extension transformation)
Numerical calculation	Data processing	Data mining	Strategy generating
(Equation solving)	(Searching)	(Matching/Reasoning)	(Transformation and reasoning)
	Expert system	Decision support system	Extension strategy generating system

In the study on contradictory problem processing in Extenics, the core tool of its application is the extension strategy generating method. In recent decades, the study on extension strategy generating method has been reflected in the following three respects:

1. Study on the formalization system of extension information-knowledge-strategy

Extenics established the logical cells of the extension model, describing various matters, affairs and relations in the real world, and the information and knowledge by basic-elements, by which, established the extension model to solve the contradictory problems. The existing object oriented methods and relational database can serve as the computer implementation method of basic-elements, with one record corresponding to one multi-dimensional basic-element and one datasheet corresponding to the "multi-dimensional basic-element set". It's shown by studies that the "extension information-knowledge-strategy formalization system" established in Extenics can effectively describe the thinking model used to treat contradictory problems by human beings.

2. Study on the computer implementation technology of the extension strategy generating method

The basic steps of the extension strategy generating method is: establish extension models of contradictory problems – conduct extension analysis and conjugate analysis – implement extension transformation – evaluate priorities. In the study on extension strategy generating systems, the computer implementation problems in various steps have been seriously discussed, and the specific implementation technology has been proposed as well.

3. Study on the extension data mining method

In the extension strategy generating process, some knowledge may be derived from professional knowledge, while some may be formed by the rules found among the existing historical data. Therefore, we must study the data mining method based on transformations, finding out the change laws from the extensive historical data, to provide the knowledge required by extension strategy generation.

At present, the studies in these three respects have been preliminarily developed.

4.5.1 Study on the "Extension Information–Knowledge–Strategy Formalization System" with Basic-element as Basic Element

With the intellectual and economic development network flourishing, when facing various problems in production practices, military activities and scientific experiments, people hope the computer may conduct creative thinking and help them come up with high-level solving strategies. This requires the computer to collect relevant information and knowledge in the objective world embarking from the subjective purpose, to generate a problem solving strategy. In other words, the computer should concisely express the collected information and knowledge regarding the goal and environment of the given problem; should generate the knowledge required to solve the problem, according to certain rules; generate the problem solving strategies from this information and knowledge and evaluate these strategies, according to other rules. Therefore, the establishment of the formalization system that can express information and knowledge and has the rules to generate knowledge, generate and evaluate strategy (referred to as the "extension information – knowledge – strategy formalization system" for short) had become the basic problem that should be currently and urgently studied.

Extenics uses basic-elements as logical cells to describe things and various relations, in the same way, the basic-element can also be used as the logical cell to express information (referred to as information elements) and knowledge, and both are simple, normal and explicit. The extension reasoning that expresses the relation between basic-elements can be used to express the rules that information generates knowledge. The extension transformation can be used as the tool to generate the contradictory problem solving strategy from the existing information and knowledge. The extension set and dependent function can be used as the quantitative tool to generate and evaluate the strategies. Therefore, to establish the above-mentioned formalization system by the theory and method of Extenics is feasible, and this system is simple, explicit, and can be operated on a computer.

4.5.2 Study on the Basic Theory and Method of Extension Strategy Generation

Strategy generation is a difficulty in decision-making science. With the social and economic development and the increasing progress of science and technology, the systems involved in decision making have become more and more complex, and the parameters to be considered have been increasing; it seems ineffective and powerless to generate strategies and make decisions by human brains only. The generation and evaluation of strategies by computer has become the key to improving the decision-making levels. In this respect, the studies at home and abroad seem insufficient. The reasons lie in two respects: one is the immature basic theory of strategy generation, and the second is that the model and method of strategy generated by computers are still to be studied.

For many years, people have introduced the support strategies of “decision support system”, “group decision support system”, “expert system”, “genetic algorithm”, “neural network”, “intelligent agent” and “management information system”, etc. in the decision-making process. But these systems can play the decision supporting role only, and the material breakthrough regarding strategy generation has been absent. Therefore, the study on a new path to generate strategies is imperative.

In the studies of the National Natural Sciences Foundation projects of the “Study on Rules of Contradictory and Conflicting Problems Processing in Decision-making System”, the “Theory and Method of Transforming Bridge”, the “Generating Method and Coordinating Problem of Key Strategies”, the “Study on Extension Marketing Method”, and the “Study on Theory and Method of Extension Planning”, as well as the Guangdong Provincial Natural Sciences Foundation project of the “Study on Conjugate Analysis of Enterprise Resources and Extension Resource”, the problem of combination of strategy generation, Extenics and computer technology has been preliminarily explored, and the basic thinking and key technologies of extension marketing strategy generating systems has been studied. It can be seen from the above subjects that:

(1) Combining decision-making science, Extenics and artificial intelligence, using computers for strategy generation and evaluation are feasible tools to improve the decision-making level and machine intelligence, and also a new path of decision-making scientification. This study has practical value in the fields of management, control, tests and information, etc. It’s a cross-research project of decision-making science, artificial intelligence and Extenics. And despite of so many difficulties, we must make great efforts to explore this path.

(2) Given that the extension model takes into consideration both quantitative relations and thing’s quality and characteristics, and describes thing’s extensibility, using the extension model as the formalization tool of strategy generation is more rational and feasible than using the mathematical model, and is easy for computer operation and human-machine integration, for processing more complicated problems.

(3) On the way to accelerate the study progress and find new paths, China is leading the world in the strategy generation by computer, which is a subject worthy of in-depth study. Therefore, it’s very valuable to discuss the computer implementation system for strategy generation by using Extenics (referred to as extension strategy generating system for short).

It can be seen that the study on the extension strategy generating system has scientific significance in the development of decision science and artificial intelligence, and the study on corresponding utility software has practical value in scientific decision-making in various trades of the national economy.

4.5.3 Study on the Theory and Study of Extension Data Mining

In many trades, people have to consider which transformations should be adopted to treat the contradictory problems, and learn what effect will be produced after implementing certain transformation. For example, at economic overheating or recession, the banks treat the problems by raising or reducing the interest. Then, can we know the function and effect of these transformations, and gain certain awareness of the changed data, range and affecting speed? On the contrary, can the relevant knowledge on these transformations be found from the previous database and the large amount of accumulated data to help the corresponding decision making? For example, when should interest be raised as appropriate, and how about its range, etc.? These problems can be found everywhere, such as the influence of tax increases and reductions on industries, the determination of patient treating prescription, and the changes of parameters in experiment programs, etc. All of these problems involve dynamic changes.

In order to find the transformations to solve contradictory problems from the historical data and to find the function of trnasformations on data, we should first theoretically apply the extension set theory and extension logic in data mining, and correspond the database/data warehouse to the extension set’s universe of discourse; in terms of the method, we can combine the database/data warehouse with the formalization system with basic-elements as cells, and establish the knowledge representation suitable for “transformation” mining pertinent to the changed data. We can establish a set of theories and methods of extesion data mining suitable for “transformation” mining through extension reasoning by using the knowledge acquired by data mining, and develop the operatible extension data mining software on the basis of these theories and methods. This has certain scientific importance in the development of the theories and methods of data mining, and practical value in the searching for problem processing strategies and the analysis of transformation function in the industries of finance, tax and medicine.

4.5.4 Study on Intelligent Processing of Contradictory Problems in Various Fields

Extenics is an interdiscipline of mathematics, philosophy and engineering. The key research direction of the combined Extenics and artificial intelligence is the intelligent processing of contradictory problems.

The establishment of extension reasoning and extension algorithm focusing on problem processing and using the description of information and knowledge by extension model [38], to enrich and develop the extension theory, and to explore the theoretical system and application of artificial intelligence will become the direction of the future combination of Extenics researchers and artificial intelligence workers. The further in-depth studies on the extension modeling method, extension reasoning technology, extension algorithm, extension classification technology, extension strategy generating technology, conjugate analysis technology, and extension searching technology, etc. will provide the technologies suitable for the intelligent processing of contradictory problems.

For more than ten years, Extenics researchers have studied the intelligent processing of contradictory problems in many fields, and achieved certain progresses:

1. Extension design

The work of computer-aided concept design and product design is the first application research, which includes the conception of new products, and the design and planning of product concepts in the fields of mechanics and building, etc.

2. Extension control

The contradictory problems in the control process and the processing of these problems by extension transformation have been studied in recent years by the scholars in the automation field, and achieved certain application results in both Mainland China and Taiwan.

3. Extension detecting

To transform an immeasurable parameter to a measurable parameter and the untestable contradictory problem to a testable problem are the tasks of extension detecting, and the relevant exploration is under progress.

With the scientific and technological development, the intelligent processing of contradictory problems will be involved in all fields. The study on the way to generate the solving strategies of contradictory problems by computer to improve the computer intelligence level has become extremely urgent. Since the network and computer have penetrated into all layers of human life and work, the full utilization of intelligent contradictory problem processing systems will become the important task in the modernization in many national economic fields. Facing the future, the intelligence will not be materially realized without the contradictory problem processing software and network, and the information platform embarking from users helps contradictory problem solutions. Therefore, the study on the theory and method of intelligent contradictory problem processing is the frontier subject for human progress and national economy, and a major subject inevitable in the progression of information-based and network-based technological fields.

In order to solve specific contradictory problems, we must study the formalization model, quantitative tool, reasoning rule and particular methods needed to treat the general contradictory problems and the contradictory problems in various fields, particularly the method and technology to develop the intelligent contradictory problem processing to the internationally advanced status. Therefore, the study on the computer-aided processing of contradictory problems of various departments is a major subject to be solved for the economy, society and national security. Through researches for many years, we believe it’s hopeful to achieve breaking-through results in the above aspects.

Chapter 5 Extension Engineering Methodology and Technology

People usually come across various contradictory problems in engineering technology and economic management. In recent decades, scholars have conducted many beneficial explorations in the study on these contradictory problems by using the basic theory and method of Extenics.

Extenics is a new discipline that studies the possibility of object extension and laws and methods of object extension and uses them in solving contradictory problems. Extension engineering is the application of the theory and method of Extenics in various fields. This chapter introduces the application methodology or technology of extension engineering in the fields of information and knowledge representation, strategy generating, data mining, marketing, planning, design, control and detect, identification, diagnosis, and searching, etc., which are collectively referred to as the extension engineering methodology.

5.1 Formalization System of Extension Information-Knowledge-Strategy

For computer-aided processing of contradictory problems, we must generate the contradictory problem processing strategy by various information and knowledge through extension transformation, to assist our decision making. In case of insufficient information and knowledge, we should also obtain the knowledge on changes from historical data by the extension data mining method. The study on these problems is attracting great interest of, and active involvement by the scholars of information science. To this end, the sections 5.1-5.3 in this chapter briefly introduce the relevant contents and preliminary study results, but the numerous problems involved are still to be further studied in-depth by the scholars in a vast extent.

5.1.1 The Necessity to Establish the "Formalization System of Information-Knowledge-Strategy"

In current artificial intelligence, the information and knowledge are represented by assorted methods, within which, each method has its advantage, as well as one drawback or another. In addition, they have a common problem that all of them lack strict theoretical system. On the other hand, it should be noted that in terms of effective knowledge and intelligence generation, the existing theories and methods are far from meeting the requirement for developing the high-level intelligent computer.

The man is posing increasingly higher requirements for the computer's intelligence level, for which, information, knowledge and intelligence are indispensible. Reference [16] studies their relations and reference [17] proposes the unified theory of "information-knowledge-strategy-action". To realize such unification, the key lies in the establishment of the formalization system of "information-knowledge-strategy-action". In other words, how the computer will concisely express the collected information and knowledge facing the goal and environment of the given problem; at the same time, how it will generate the knowledge needed when solving the problems according to certain rules; and how it will generate the strategies to solve the problems form such information and knowledge, and evaluate the strategies. Therefore, the establishment of the formalization system that can explicitly represent information and knowledge and has the rules to generate knowledge, and produce and evaluate the strategies has become the basic problem that should be urgently studied by now.

The extension theory established the basic-elements – matter-element, affair-element and relation element to describe matter, affair and relation, which can be served as the logical cells to describe information and knowledge. Its established extension reasoning rule can be used to generate knowledge, and the extension transformation rule can be served as the basis for strategy generation; the extension set and dependent function can be served as the quantitative tool to generate strategies, and the extension evaluation method can be used to evaluate and sift the strategies; thus, the “formalization system of information-knowledge-strategy based on extension theory” can be established on the basis of the extension theory and method.

To study this system, we first give the information representation methods by basic-elements and the knowledge representation methods based on extension rules.

5.1.2 Information Representation method by Basic-elements

Information has the universal, dependent (barrier indivisible), measurable, identifiable, processible, transmittable, sharable and other properties. Information is widespread in the natural world, the biological world, and the human society. Information is assorted, multi-aspect and multi-hierarchy, with its own structure and components. Information can be classified by different methods from different angles.

From the viewpoint of epistemological meaning, information is the natural description of the moving state and changing (connecting) mode of objects [18]. Here the information has hierarchies, i.e. grammatical information hierarchy, semantic information hierarchy and pragmatic information hierarchy. The most basic grammatical information hierarchy only considers the relation between the object moving states; the semantic information hierarchy considers both of such relation and all its implications; the highest pragmatic information hierarchy considers both of such relation and all its implications, as well as the further effect or value of such relation and implications for the information user.

The definitions of information are diversified. From the angle of Extenics, the representation of grammatical information by basic-elements is studied by using the basic-elements and compound elements. The information represented by basic-elements is collectively called information elements. The grammatical information can be represented by different basic-elements according to its different expression modes.

The semantic and pragmatic information is specific to certain grammar information. As to the semantic information, reference [18] treats the problem of representing the implications of object moving state and changing mode by adopting the concept of referential logic; as to the pragmatic information, reference [18] treats the problem of representing the value of object moving state and changing mode by adopting the concept of effectiveness, i.e. solves the description of the value size of various object moving states for the subject. This section only introduces the grammatical information representation by basic-elements, while using the referential logic and effectiveness as two evaluation indicators of the grammatical information basic-element (i.e. information element). The expression of semantic, pragmatic and changing information through establishing the extension set of information elements will be discussed elsewhere.

The representation of grammatical information by basic-elements is as follows.

1. Representation of statement information by matter-elements

Statement information refers to the information expressed by statement grammar, including the information on matter, concept and proposition, etc., all of which can be expressed by matter-elements. Such as data and literature, etc., which are called information because they have the informative property, i.e. “have the characteristics of imparting knowledge or spreading information, and the educational property”.

For example, “there is a 2-aged Siberian tiger in the Guangzhou Zoo in September, 2006” is statement information, and can be expressed by formalized matter-elements as

$$M_1=\begin{bmatrix} \text{Siberian tiger N,} & \text{age,} & 2 \\ & \text{location,} & \text{Guangzhou Zoo} \\ & \text{time,} & 9,\ 2006 \end{bmatrix}$$

For another example, that “professor A is a famous economist of university B” is also statement information, and can be expressed by formalized matter-elements as

$$M_2=\begin{bmatrix} \text{A,} & \text{professional title,} & \text{professor} \\ & \text{work unit,} & \text{university B} \\ & \text{specialty,} & \text{economics} \\ & \text{fame,} & \text{high} \end{bmatrix}$$

Again, “the global sales volume of ‘Who Moved My Cheese?’ written by Spencer. Johnson exceeds 20 million copies” is also statement information, and can be expressed by formalized matter-elements as

$$M_3=\begin{bmatrix} \text{Who Moved My Cheese?,} & \text{author,} & \text{Spencer•Johnson} \\ & \text{sales volume,} & \text{>20 million copies} \end{bmatrix}$$

2. Representation of action information by affair-elements

Action information refers to the information expressed by action grammar, mostly the “information serving as a process”, which can be expressed by formalized affair-elements. After receiving such information, one may know certain affairs or processes. In this sense, such information is the action of “informing, the spreading of the knowledge or message on certain fact or situation, and the fact of the informing action or certain informed affair”.

For example, “the 11th National Annual Extenics Conference was held in Harbin Institute of Technology from August 14, 2006 to August 17, 2006, by the Extension Engineering Specialized Committee (EESC) of Chinese Association for Artificial Intelligence (CAAI)” is action information, and can be expressed by formalized affair-elements as

$$A_1=\begin{bmatrix} \text{hold,} & \text{dominating object,} & \text{11th National Annual Extenics Conference} \\ & \text{acting object,} & \text{EESC of CAAI} \\ & \text{time,} & \text{14-17, August, 2006} \\ & \text{location,} & \text{Harbin Institute of Technology} \end{bmatrix}$$

For another example, “Smith bought two music CDs in Beijing in September, 2006” is also action information, and can be expressed by formalized affair-elements as

$$A_2=\begin{bmatrix} \text{buy,} & \text{dominating object,} & \text{music CDs} \\ & \text{acting object,} & \text{Smith} \\ & \text{time,} & \text{September 2006} \\ & \text{quantity,} & 2 \\ & \text{location,} & \text{Beijing} \end{bmatrix}$$

3. Representation of relation information by relation elements

Relation information refers to the information expressed by relation grammar, and can be expressed by relation elements. After obtaining such information, one may know such a relation.

For example, that "the counties N_1 and N_2 maintained very close diplomatic relations during 1959-1999", and "N_3 and N_4 are man were wife during 1959-1999", are both relation information, and can be expressed by formalized relation elements as

$$R_1 = \begin{bmatrix} \text{diplomatic relation}, & \text{antecedent}, & \text{country } N_1 \\ & \text{consequent}, & N_2 \\ & \text{time}, & <1959,1999> \\ & \text{degree}, & 100 \end{bmatrix}$$

$$R_2 = \begin{bmatrix} \text{conjugal relation}, & \text{antecedent}, & N_3 \\ & \text{consequent}, & N_4 \\ & \text{time}, & <1959,1999> \end{bmatrix}$$

4. Representation of complicated information by the operation formula of basic-elements or compound elements

Much information is complicated information that includes both statement information and action information, and may include relation information, which should be expressed by compound elements.

For example, that "enterprise E successfully develops a new anticancer agent D in September, 2006" is complicated information, and can be expressed by compound elements as

$$A_1 = \begin{bmatrix} \text{develop}, & \text{dominating object}, & M \\ & \text{acting object}, & \text{enterprise } E \\ & \text{time}, & \text{September, 2006} \\ & \text{degree}, & \text{successfully} \end{bmatrix}$$

$$M = \begin{bmatrix} \text{medicine } D, & \text{function}, & \text{anticancer} \\ & \text{type}, & \text{brand new} \end{bmatrix}$$

For another example, "an electrical appliances shop will hold a concessional sale program of LCD colored TV sets on its opening day" is a piece of complicated information, and can be expressed by compound elements as

$$A_2 = \begin{bmatrix} \text{hold}, & \text{dominating object}, & A_{22} \\ & \text{acting object}, & \text{an electrical appliances shop} \\ & \text{time}, & \text{on its opening day} \end{bmatrix}$$

$$A_{22} = \begin{bmatrix} \text{sell}, & \text{dominating object}, & \text{LCD colored TV sets} \\ & \text{mode}, & \text{concessional} \end{bmatrix}$$

Again, "enterprises E_1 and E_2 develop a new product P after 2 years' closed cooperation" is also a piece of complicated information, and can be expressed by the working equation and relation element and affair-element as $A_3 \wedge R$, wherein

$$A_3 = \begin{bmatrix} \text{develop}, & \text{dominating object}, & \text{new product P} \\ & \text{acting objects}, & \text{enterprises } \mathrm{E}_1 \wedge \mathrm{E}_2 \end{bmatrix}$$

$$R = \begin{bmatrix} \text{cooperative relation,} & \text{antecedent}, & \text{enterprise } \mathrm{E}_1 \\ & \text{consequent}, & \text{enterprise } \mathrm{E}_2 \\ & \text{degree,} & \text{close} \\ & \text{time,} & \text{2 years} \end{bmatrix}$$

5.1.3 Knowledge Representation Based on Extension Rules

Knowledge representation, knowledge acquisition and knowledge processing are the three pillars in knowledge engineering, but the knowledge representation is its core. The knowledge representations currently and commonly used in artificial intelligence are predicate logic, production knowledge representation, semantic network, frame representation, fuzzy logical representation, state space method, problem reduction method, and object-oriented knowledge representation, etc. These knowledge representations have their respective characteristics, for example, the production method is natural, the semantic network is hierarchical, the frame is universal, and the fuzzy logic is applicable to fuzzy knowledge, etc., but they also have their respective limitations. For example, the production method is for representing the surface knowledge but extremely difficult for representing deep knowledge; the frame fixity often leads to inconsistence between the represented result and its prototype, etc. The capacity for knowledge representation directly influences the reasoning effectiveness and the capacity for knowledge acquisition. Therefore, several problems to be urgently solved are encountered during the construction of intelligent expert systems: the first is the difficulty in knowledge acquisition that includes the contradiction and incompatibility between the knowledge provided by domain experts, for which the knowledge representation that is effective and applicable to contradictory problems should be designed; the second is that the existing expert systems must include thousands of rules because of its scarce self-study capacity, causing difficulties in maintenance and management works, which is obviously relevant to the knowledge representation; the third is that it’s difficult to express the deep knowledge on the functions and the inherent structure of complicated system because the limited knowledge representation capacity, such as the semantic logic and pragmatic logic, etc. in knowledge; the fourth is that creative thinking still hardly can “be called into play” in the intelligence architecture system.

The rules of Extenics are collectively called extension rules, including extension rule, conjugate rule, transformation rule, logical operation rule of basic-element, and operation rule of transformation, etc., which were introduced in 2.8 in this book. Some drawbacks of the above knowledge representations can be overcome on the basis of the knowledge representation of these rules. First of all, it’s concise, normalized, and easy for operation. Second, the multiple possibilities for object extension can be systematically described by their extensibility, which provides new theory and methods to improve the creative thinking capacity and strategy generating technology in artificial intelligence. Third, new technology and methods of knowledge acquisition can be obtained by the extension equation of basic-elements. Therefore, this kind of knowledge representation will play an important role in the knowledge representation technology of artificial intelligence.

In addition, the knowledge in the current knowledge system or expert system is mostly surface knowledge. While to solve complicated problems, particularly the contradictory problems, we must solve the deep knowledge acquisition, strategy generation, storage, representation, processing and application, only so we can improve the capacity and flexibility for problem solving. The extension method studies the rules and methods to solve contradictory problems from both qualitative and quantitative angles, provided new tool for solving the deep knowledge acquisition and processing in the knowledge base system.

Some simple knowledge can be expressed directly by basic-elements, such as the knowledge expressed by predicates; the knowledge expressed by production rules can be expressed by the production rules of basic-elements; the knowledge expressed by semantic network can be expressed by the semantic networks of basic-elements; the knowledge expressed by frames can be expressed by multi-dimensional basic-elements, etc. For details, see also the relevant knowledge in reference [6].

Much knowledge can be considered as the relations between information elements, and such knowledge can be expressed by the relations of basic-elements based on extension rules [19]. According to the relations between basic-elements in Extenics, the knowledge expressed by the extension and conjugation of basic-elements and the implication of transformations can be divided into six classes:

1. Divergent knowledge

The knowledge that indicates the divergent relations of object properties is referred to as divergent knowledge. According to the divergence rule of basic-elements, the divergent knowledge can be expressed by the divergence of basic-elements:

$$(O_1, c_1, v_1) \dashv (O_i, c_j, v_k), \quad i = \mathbf{1}, \mathbf{2}, \mathbf{3} \cdots n_1;\ j = \mathbf{1}, \mathbf{2}, \mathbf{3} \cdots n_2; k = \mathbf{1}, \mathbf{2}, \mathbf{3} \cdots n_3.$$

For example, every advantage has its disadvantage, and all medicine has toxicity to some degree. Such knowledge indicates that one object has multiple characteristics, some are advantageous, but some are harmful; if c_1 indicates the advantageous characteristic of certain medicine A, while c_2 indicates its harmful characteristic, the knowledge can be expressed by

$$\left(\text{medicine A}, c_1, v_1\right) \dashv \left(\text{medicine A}, c_2, v_2\right)$$

This class of knowledge "with single object and multiple characteristics" can be expressed by the following equation:

$$\left(O, c_1, v_1\right) \dashv \left(O, c_i, v_i\right), i = 1, 2, \cdots, n.$$

For another example, apart from the fountain pen, there are many objects that can "write", and such knowledge can be expressed by

$$\left(\text{fountain pen, function, write}\right) \dashv \begin{cases} (\text{brush pen, function, write}) \\ (\text{chalk, function, write}) \\ (\text{carbon pen, function, write}) \\ (\text{dip pen, function, write}) \\ .... \end{cases}$$

There are many similar objects with the same characteristic value, and such knowledge can be expressed by the following equation:

$$\left(O, c\ , v\ \right) \text{—|} \left(O_i, c\ , v\ \right), i = 1, 2, \cdots, n$$

2. Correlative knowledge

Knowledge indicates the correlation between objects which is referred to as correlative knowledge. According to the correlation rule of basic-elements, correlative knowledge can be expressed by the correlation of basic-elements:

$$(O_1, c_1, v_1) \sim (O_2, c_2, v_2)$$

For example, the product profits and cost are closely correlated, which can be expressed as:

$$\left(\text{product } P,\ \text{profits}, a\right) \sim \left(\text{product } P,\ \text{cost}, b\right), \quad a = f\left(b\right)$$

For example, the more deadweight a boat is, the deeper its draught, which can be expressed as:

$$\left(\text{boat } B,\ \text{deadweight}, a_1\right) \sim \left(\text{boat } B,\ \text{draught}, b_1\right), \quad a_1 = f\left(b_1\right).$$

3. Implicative knowledge

Knowledge indicates the implicative relation between objects which is referred to as implicative knowledge. According to the implication rules of basic-elements, the implicative knowledge can be expressed by the implication of basic-elements:

$$(O_1, c_1, v_1) \Rightarrow (O_2, c_2, v_2)$$

For example, if a bacterium is spherical, with chain-type growth structure, and Gram-positive dye strain, this bacterium is streptococcus, expressed by

$$\begin{bmatrix} \text{bacterium } A, & \text{form}, & \text{spherical} \\ & \text{growth structure}, & \text{chain-type} \\ & \text{dye strain}, & \text{gram-positive} \end{bmatrix} \Rightarrow \left(\text{bacterium } A, \text{type, streptococcus}\right)$$

4. Opening-up knowledge

Knowledge indicates the combining or decomposing results of objects which is referred to as opening-up knowledge. According to the extension rule of basic-elements, the opening-up knowledge can be expressed by the extension of basic-element as:

$$(O_1, c_1, v_1) \oplus (O_2, c_2, v_2) = \begin{pmatrix} O, c_1, v_1' \\ \quad c_2, v_2' \end{pmatrix}$$

$$(O\ , c\ , v) / \{ (O_i, c_i, v_i), i = 1, 2, 3 \cdots n \}$$

For example, “sugar and water put together can be dissolved into syrup”, which can be expressed as

$$\left(\text{sugar } O_1,\ \text{phase},\ \text{solid}\right)\oplus\left(\text{water } O_2,\ \text{phase},\ \text{liquid}\right)=\left(\text{syrup} O,\ \text{phase},\ \text{liquid}\right)$$

For another example, “the cost for computer assembly is the sum of the cost for its parts and the cost for the assembling labor”, and this knowledge can be expressed as

$$\left(\text{computer assembly } O,\quad \text{cost},\quad a\right)/\{\left(\text{mainboard } O_1,\quad \text{cost},\quad a_1\right),\left(\text{hard disk } O_2,\quad \text{cost},\quad a_2\right),\left(\text{memory } O_3,\quad \text{cost},\quad a_3\right),\\ \cdots,\left(\text{assembler } O_n,\quad \text{labor cost},\quad a_n\right)\}$$

5. Conjugate knowledge

The knowledge expressed by the relation of the object’s conjugate parts is referred to as conjugate knowledge. According to the conjugate rule, the conjugate knowledge can be expressed by conjugation, including the imaginary/real conjugate knowledge, soft/hard conjugate knowledge, latent/apparent conjugate knowledge, and negative/positive conjugate knowledge.

This knowledge is very useful in solving contradictory problems, but its representations are difficult to a certain extent, which can be further studied by the interested readers.

6. Implicative knowledge on transformations

The conductive transformation rules in Extenics can be expressed by the implication of the transformations, which indicates the changing knowledge, and can be expressed by the following expression:

$$(B_1 \sim B_2)\wedge(T_{B_1}B_1 = B_1')\models({}_{B_1}T_{B_2}B_2 = B_2')$$

denoted as $T_{B_1} \Rightarrow {}_{B_1}T_{B_2}$ for short.

The implicative knowledge of transformations includes the conjugate transformative knowledge, which is not discussed in detail here, and can be referenced to the part of conjugate transformations.

The common sense of people and the knowledge in various specialties are usually very complicated, which sometimes should be expressed by the relation of compound elements, and sometimes by the operation formula of compound elements or basic-elements, which are collectively called compound knowledge. The representation of compound knowledge is to be further studied.

Knowledge is the regular product of information processing. Knowledge is the concept in the category of epistemology, which expresses the object’s moving state and state changing laws [16]. Knowledge exists relative to the cognitive subject. Based on such a definition of knowledge, we can divide the knowledge into form knowledge, content knowledge and effectiveness knowledge. The form knowledge is related to the grammatical information concept of the epistemological information; the content knowledge is related to the semantic information of the epistemological information; the effectiveness knowledge is related to the pragmatic information of the epistemological information. Therefore, the expressions of various kinds of knowledge by basic-elements and the knowledge generating method can be given according to the above-mentioned representation of grammatical information by basic-elements and the establishment method of extension set, which are not described in detail herein and will be technically discussed elsewhere.

5.1.4 Formalized Representation of Strategy

Given problem $P = G * L$, $G = (O_G, c_G, v_G)$, and $L = (O_L, c_L, v_L)$. Suppose the objects of the goal basic-element *G* and condition basic-element *L* of *P* as a whole constitute the universe of discourse *U*, $K(G, L)$ indicates the contradictory degree of problem *P*, if $K(G, L) < 0$, then *P* is a contradictory problem. If there is transformation $T = (T_U, T_K, (T_G, T_L))$ to let $T_K K(T_G G, T_L L) > 0$, then *T* is called the extension strategy to solve the contradictory problem. The extension strategy is the extension transformation or the operation formula of extension transformations that can transform the contradictory problem to non-contradictory problem.

In terms of transformation objects, extension strategies can be divided into five types as follows:

1. Extension strategy formed by the transformation of universe of discourse

If there is transformation $T_U : T_U U = U'$ to let $T_K K(G, L) > 0$ in the new universe of discourse U', wherein T_K may be a unitary transformation, then the transformation T_U of universe of discourse is the extension strategy to solve the contradictory problem *P*.

2. Extension strategy formed by the transformation of dependent criterion

If there is transformation $T_K : T_K K = K'$ to let $K'(G, L) > 0$ under the new dependent criterion, then the transformation T_K of dependent criterion is the extension strategy to solve the contradictory problem *P*.

3. Extension strategy formed by the transformation of element (goal or condition)

Transformation of element refers to the extension transformation (T_G, T_L) of the problem's goal or condition, which may be in the following cases:

(1) Goal is changed but condition unchanged, i.e. (T_G, e);

(2) Goal is unchanged but condition changed, i.e. (e, T_L);

(3) Both goal and condition are changed, i.e. (T_G, T_L) 。

Because both the goal and the condition can be expressed by basic-elements, transformation (T_G, T_L) is actually transformation of basic-elements. If this transformation results in $K(T_G G, T_L L) > 0$, then the transformation (T_G, T_L) of basic-elements is the extension strategy to solve the contradictory problem *P*.

4. Extension strategy formed by conductive transformation

Particular attention should be paid to the conductive transformation among transformations, the contradictory problem cannot be solved directly by certain transformation s which will be solved by its conductive transformation.

In case of condition basic-element *L*, if the contradictory problem cannot be solved through direct transformation $T_L L$, we can obtain the correlative basic-element $L \sim L'$ of *L* by correlative analysis, if there are transformation $T_{L'} L' = L''$ and conductive transformation $T_{L'} \Rightarrow {}_{L'}T_L$, ${}_{L'}T_L L = L^*$, to let $K\left(G, L^*\right) > 0$, then the conductive transformation $T_{L'} \Rightarrow {}_{L'}T_L$ is the extension strategy to solve the contradictory problem *P*.

5. Extension strategy formed by the operation formula of extension transformation

The contradictory problems are solved sometimes by direct application of one extension transformation mentioned above, and sometimes by the operation formula of several transformations, for details see the relevant content in this book, which is not discussed here.

The above extension transformation, operation formula of extension transformations and conductive transformation are formalized representations of extension strategies. When solving contradictory problems, particularly complicated contradictory problems, some strategies may be very complicated that must be represented by the compound or operation formulas of basic extension transformations. For the generating method and technology of extension strategy, please reference to the relevant contents in Chapter 4 and 5.2 of this book.

5.1.5 Block Diagram to Establish the “Formalization System of Extension Information-Knowledge-Strategy”

By the above formalized representations of information, knowledge and strategy by basic-elements, we can study the method to generate knowledge from information and the method to generate strategy from information and knowledge – extension strategy generating method, to form the “formalization system of extension information-knowledge-strategy”. This system does not only discuss the above representations, but also studies the methods and rules to generate strategy from information and knowledge, mainly including ① the extension transformation method and rules to generate strategy directly from information; ② the extension transformation method and rules to generate strategy from knowledge; ③ the method and rules to generate evaluation strategy by extension set and dependent function. People can generate problem solving strategies by these methods and rules, so as to form the extension strategies base, which provides the intelligent contradictory problem processing with formalization tools.

The block diagram of the system establishing process from formalized representation of information and knowledge, to strategy generating, to problem processing (intelligence forming) is shown as Figure 5.1.

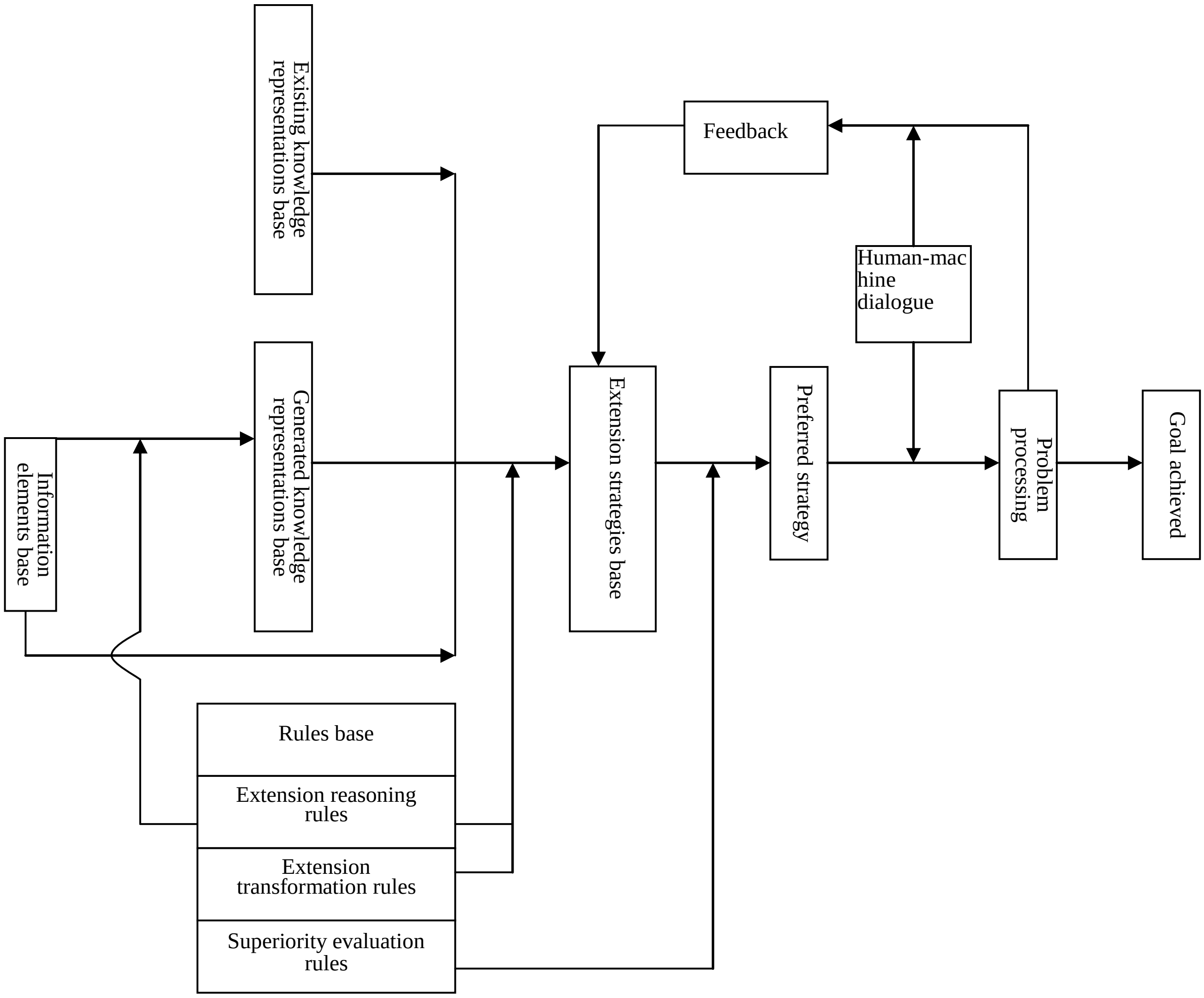


Figure 5.1 Block Diagram to Establish "Formalization System of Extension Information-Knowledge-Strategy"

5.2 Practical Technology for Extension Strategy Generating Systems

5.2.1 Basic Ideas of Extension Strategy Generating Systems

In Extenics, the tool for resolving incompatible problems is extension transformations and the basis for set theory is extension sets. The core of Extenics is to "change insensible to knowable", "change wrong to right", "change infeasible to feasible", and "change 'not belong to' to 'belong to" etc. If computers can be creative and generate strategies through utilizing them to deal with the dynamic changes of thing's properties, and regard extension transformation as the tool for resolving incompatible problems, it will have important significance to improve the intelligence capability of machine. Therefore, we studied the implementation system of computer for generating strategy which is based on Extenics and extension methods, ESGS for short (Extension Strategy Generating Systems).

The system combines extension methods and the current artificial intelligence technology, database technology, visualization technology and object-oriented technology etc. together. According to current data, it makes standard data processing with basic-element representation systems and establishes basic databases. Through the analysis of basic database and according to the rules in "rule base", it finds incompatible problems and places them in "problem base". Then it confirms material underlying problems according to extension reasoning rules and human-machine dialog methods, establishes "extension transformation base" with extension methods, generates various resolution strategies and gets the strategy superiorities with superiority evaluation methods, providing suitable programs for decision makers. It is a process of finding problems, analyzing problems and generating solution strategies with computers through imitating human beings, which can help decision makers to generate strategies for solving incompatible problems.

Main steps for establishing ESGS are as follows:

Step 1 Establish problem's extension models, based on which make information extraction, and establish a foundation base. To study strategy generating technology, we need to extract valuable information from original mass data first, i.e. standardize the existing data information with information and knowledge representation system based on basic-elements and establish basic database according to problem requirements, which is called a basic-element base.

Step 2 Analyze problems and establish extension models of core problem according to problems' goal requirements and conditional restrictions through human-machine interaction (or understanding of natural language, but current levels are immature).

Step 3 Extend basic-elements involved in the problems based on extension reasoning rules. According to the universe of discourse, dependent criteria and basic-elements involved in core problems get various extension possibilities through extension rules.

Step 4 Generate strategies through using extension transformation and conductive rules and conjugation rules. Extension transformation is the basic technology for generating strategies. Then through using the basic-elements extended in Step 3 and using basic transformations, the operation formula of transformations and conductive rules or conjugation rules, generate various resolving transformations of incompatible problems, i.e. so-called extension strategies.

Step 5 According to superiority evaluation methods evaluate and select the strategies. Then sort the strategies according to superiority and select those with higher superiority as the reference strategies for decision makers.

The *Extension Strategy Generating System* [20] published by Science Press in 2006 introduces the theoretical basis, basic approach and practical technology of ESGS in detail. This section will simply introduce the practical technology and functional modules in ESGS. See more details in the monograph above.

5.2.2 Data Structure Type of ESGS

The data structure type of ESGS refers to the original data type in computer system which can express basic-element and transformation etc., i.e. express relevant structure of ESGS through using the existing data type in computer processor.

1. Type of relational data table

(1) Presentation of Matter-element Data Table

Suppose n-dimension matter-element

$$M = \begin{bmatrix} O_M, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

It corresponds with the data table below:

Table 5.1 Matter-element Data Table

Matter-element (M) No.	Matter Name	c_1	c_2	…	c_n
M_i	O_M	v_1	v_2	…	v_n

(2) Presentation of Affair-element Data Table

Suppose n-dimension affair-element

$$A = \begin{bmatrix} O_A, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

It corresponds with the data table below:

Table 5.2 Affair-element Data table

Affair-element (A) No.	Action Name	c_1	c_2	…	c_n
A_i	O_A	v_1	v_2	…	v_n

(3) Presentation of Relation-element Data Table

Suppose n-dimension relation-element

$$R = \begin{bmatrix} O_R, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$$

It corresponds with the data table below:

Table 5.3 Relation-element Data Table

Relation-element (R) No.	Relation Name	c_1	c_2	…	c_n
R_i	O_R	v_1	v_2	…	v_n

(4) Presentation of Extension Transformation Data Table

Extension transformation can be expressed in affair-element form as

$$T = \begin{bmatrix} O_T, & c_1, & v_1 \\ & c_2, & v_2 \\ & c_3, & v_3 \\ & c_4, & v_4 \\ & c_5, & v_5 \\ & c_6, & v_6 \\ & c_7, & v_7 \end{bmatrix} = \begin{bmatrix} \text{Transformation}, & \text{control object} & v_1 \\ & \text{receiver object} & v_2 \\ & \text{result} & v_3 \\ & \text{agent object} & v_4 \\ & \text{method}, & v_5 \\ & tool, & v_6 \\ & time, & v_7 \end{bmatrix}$$

Basic transformation and conductive transformation can be shown with the same data table as follows:

Table 5.4 Data Table for Basic Transformation and Conductive Transformation

Transformation No.	Transformation Name	c_1	c_2	c_3	c_4	c_5	c_6	c_7	…	Transformaton Type	Conductive Transformation
T_i	O_T	v_1	v_2	v_3	v_4	v_5	v_6	v_7	…	…	…

Corresponding information can be increased if conductive transformation exists.

2. Structure style type

Structure style is a common important data type, which can combine data with different types into an organic whole. It is equal to relational database table, which can also express basic-element and transformation etc.

3. Class type

Object-oriented class is a package composed of a group of data items that describe object property or status and operations acted on these data items. The data therein is called data member and the operation is called member function.

The properties of basic-elements can be shown with data members while the extension transformations on them can be shown with member functions.

5.2.3 ESGS Analysis

1. System analysis thinking (Framework)

System analysis is a key link of ESGS. ESGS system analysis is a series of processes that use the basic theory and method that adopt Extenics, makes modeling and extensible analysis for incompatible problems so as to establish the relevance tree and extension transformation implication tree of problems and generates extension strategies for resolving contradictory problems. See its system analysis framework in Figure 5.2.

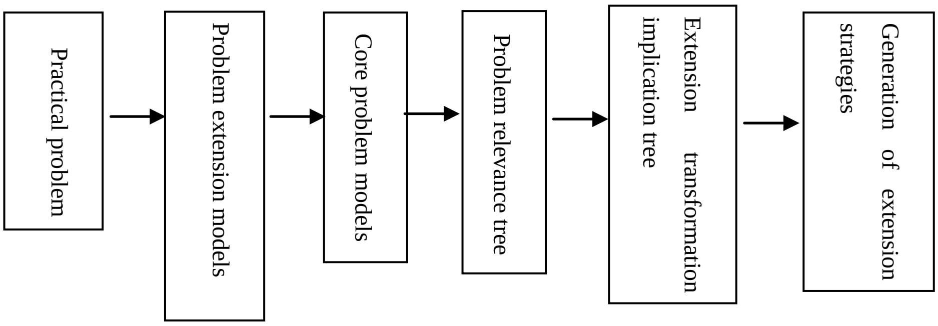


Figure 5.2 Framework of ESGS Analysis

2. Establishment of extension models for incompatible problems

Extenics studies the contradictory problems in the objective world. ESGS aims to resolve incompatible problems, thus the first step is to establish the extension models of problems.

To establish the extension models of problems, we must present the goal and condition of problems in basic-element form first. It includes two aspects. First, make accurate problem definition, grasp principal contradictions, simplify, embody and quantify the problem; second, express the problem correctly through a basic-element knowledge presentation system.

The other important step for modeling is structuring core problems. In a practical application, the core problem of the problems is relevant to its restriction and resolution. Due to the objectively existed or artificially offered restrictions, some goals that we want to achieve receive corresponding restraints as well. See also the method of establishing extension models for incompatible problems in 4.1 of this book.

3. Correlation network and implication tree of problems

For the core problem of problem, correlation analysis methods of basic-elements can be adopted to make correlation analysis for its conditions so as to structure the correlation network and extension transformation implication tree of problems; or the implication analysis methods of basic-elements can be adopted to make implication analysis for its goals so as to structure the implication tree of problems.

(1) Correlation network of the problem

If certain dependence exists among the values of one basic-element and other basic-elements on a certain property and among the values of the same basic-elements or those of the same cognate on certain properties, we call it correlation. See also the definition of correlation in 2.2 of this book.

Correlation analysis aims to find the correlation network of problems. In the objective world, any object is closely connected with other things and so is among concepts. When we express these objects or goals with basic-elements, there is a network structure among them, forming correlation network. Correlation network can be rather complicated and only simpler correlation trees are discussed here.

For core problem $P_0 = g_0 * l_0 = (Z_0, c_{0s}, X_0) * (Z_0, c_{0t}, c_{0t}(Z_0))$, the class basic-element corresponding to l_0 is recorded as L_0.

Make correlation analysis for L_0 first. Suppose the class basic-elements relating to L_0 are $L_{01}, L_{02}, \ldots, L_{0m}$ and basic-elements relating to L_{0i} are $L_{0i1}, L_{0i2}, \ldots, L_{0ih_i}$. Establish the correlation tree of problems as Figure 5.3.

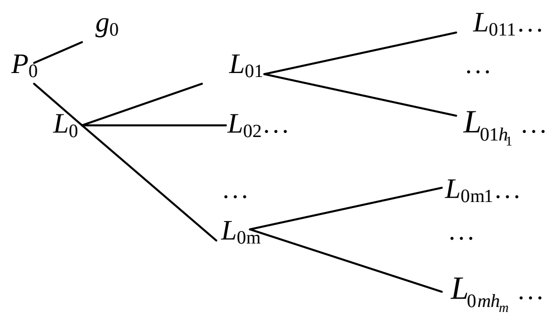


Figure 5.3 Correlation Tree of Problems

According to the above correlation tree, the initial correlation tree can be formed.

Some correlations are not bidirectional. In a problem correlation tree, our primary concern is correlative factors that may influence condition l_0, while its corresponding correlation tree is a directional tree, which is called initial correlation tree. See Figure 5.4.

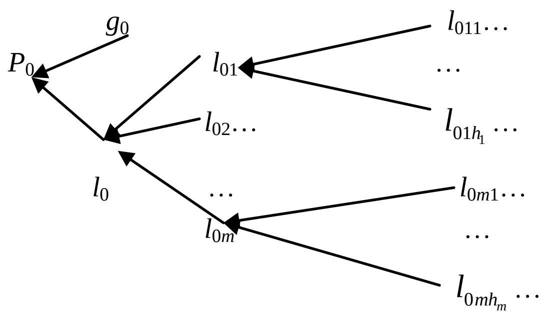


Figure 5.4 Initial Correlation Tree of Problems

(2) Implication Tree of the problem

For the implication analysis of a core problem $P_0 = g_0 * l_0$, it is usually the implicaiton analysis of g_0 (can also be the implication analysis of l_0, which is less used). The inferior basic-elements of g_0 are usually found through implication analysis when g_0 is hard to be realized. If inferior basic-elements are easy to be realized, the primal problem can be realized.

For core problem $P_0 = g_0 * l_0$, the class basic-element corresponding to g_0 is recorded as G_0. Suppose the class basic-elements of implication G_0 are $G_{01}, G_{02}, \ldots, G_{0m}$ and the basic-elements of implication G_{0i} are $G_{0i1}, G_{0i2}, \ldots, G_{0ih_i}$. Similar to the correlation tree of problems, the implication tree as shown in Figure 5.5 can be established.

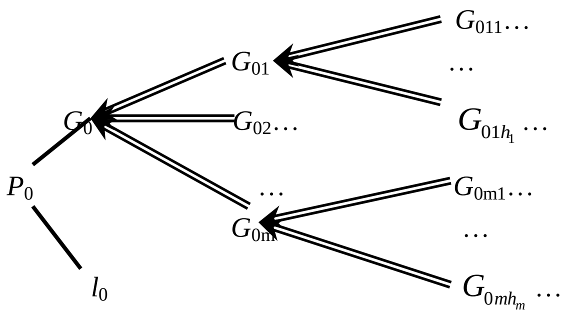


Figure 5.5 Implication Tree of Problem

Initial implicaiton tree is formed among corresponding example basic-elements as shown in Figure 5.6.

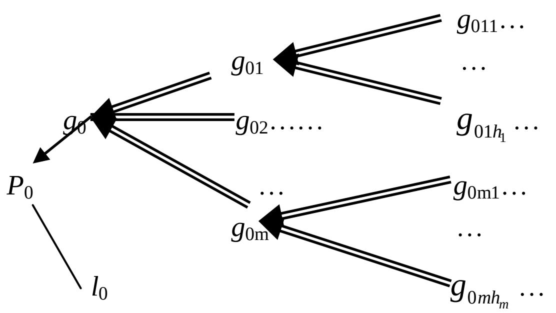


Figure 5.6 Initial Implication Tree of Problem

(3) Correlation-Implication Complex Tree of the problem

In the process of resolving lots of incompatible problems, sometimes both relevance analysis of conditions and implication analysis of goals are needed to get strategies for resolving incompatible problems. Thus the correlation-implicaiton complex tree needs to be structured, i.e. Combine above two kinds of trees together.

For convenient analysis and introduction, only condition analysis is selected as examples for the introduction.

4. Implication tree of extension transformations

Due to the properties of correlation and correlation networks, the changes within one basic-element will cause the change of other correlative basic-elements. The change is mutually transmitted in one correlation network. Therefore, according to the conductive transformation between correlative network and basic-elements therein, an implication tree of extension transformations can be generated.

Generally speaking, for basic-element $B_{0,}$ suppose $B \sim B_0$, then there will be $T_B \Rightarrow {}_BT_{B_0}$ or $T_{B_0} \Rightarrow {}_{B_0}T_B$.

Thereinto, T_B is the active transformation of basic-element B, ${}_BT_{B_0}$ refers to the conductive transformation of B_0 caused by the active transformation of B; T_{B_0} is the active transformation of B_0, ${}_{B_0}T_B$ refers to the conductive transformation of B caused by the active transformation of B_0.

For the initial relevance tree above, if class basic-elements L_{01}, L_{02}, …, L_{0m} and L_0 are AND related, L_{0i1}, L_{0i2}, …, L_{0ih} and L_{0i} are also AND related, then the implication tree of extension transformations as shown in Figure 5.7 can be generated.

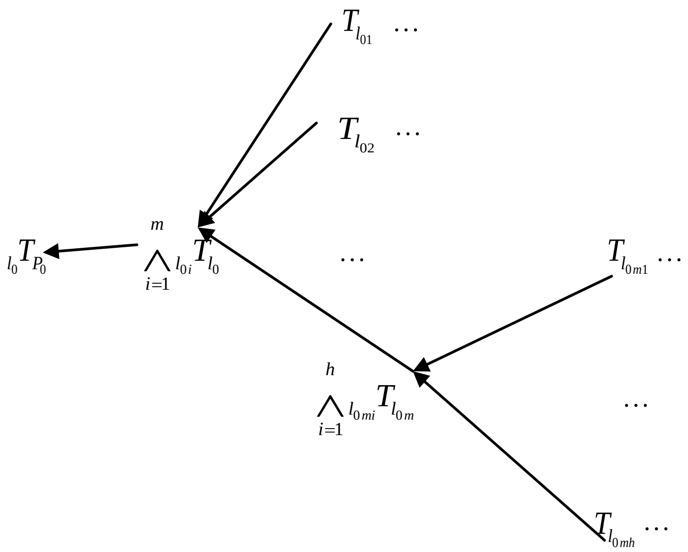


Figure 5.7 Implication Tree of Extension Transformations

It shows the transformation of l_{0m1}, …, l_{0mh} etc., implies the conductive transformation of l_{0m} and finally causes the change of P_0, which permits us to make use of correlation network and implication tree to generate the strategies for resolving incompatible problems so that accordingly resolve them.

If class basic-elements $L_{01,}$ $L_{02,}$ …, L_{0m} and L_0 are OR related, L_{0i1}, L_{0i2}, …, L_{0ih} and L_{0i} are also OR related, then above AND transformation should be changed to OR transformation. See more details in 2.2.

5. Problem correlation tree about extension transformations

The implication tree of extension transformations will change the initial correlation tree of problems to a new problem correlation tree, which is called the problem correlation tree about extension transformations. It will be introduced in the extension strategy generating technology below through combining extension transformations.

The problem correlation tree about extension transformations can clearly show the change results of incompatible problems. The active transformations of implication tree of extension transformations that change the compatibility of incompatible problems from ≤ 0 to >0 are just the resolving transformations for resolving incompatible problems, i.e. extension strategies.

5.2.4 Extention Strategy Generating Technology

1. Data warehouse technology

The data structure of an extension strategy generating system is classified into two types, one is data table type and the other is structure style type and class type. The technology adjustable to data table type is database and data warehouse while that adjustable to the second type is object-oriented programming technology. We only discuss application database and data warehouse technology here.

There are three methods to organize the data in data warehouse: virtual memory means, memory means based on relational table and multidimensional database memory means. Virtual memory means is the organizational form of data in virtual data warehouse. It has no special data warehouse memory and the data in data warehouse still exists in source database. It just finishes the function of multidimensional analysis through tools in semantic layer based on the users' multidimensional needs; the organization in relational data warehouse storages the data in data warehouse at the list structure in relational database. It finished the function of data warehouse under the management of metadata, which is called ROLAP; the organization in multidimensional database directly faces the data organizational form of OLPA analytical operation, which is called MOLAP. ROLAP technology is adopted in ESGS. It requires users to write query language in SQL according to star or snow flake data mode.

2. Design of data warehouse

(1) Technical Implementation Based on Relational Database

Compared with special multidimensional databases, although the expression of multidimensional concepts of relational database is not so natural, it is also a practical and feasible program when current relational databases are widely used, e.g. both Sybase and Informix adopt this technology. However, the key of this technology is identifying how to express multidimensional concepts with the two dimensional tables of relational databases. In fact, relational structure can adjust to the expression and storage of multidimensional data better. Relational databases divide the multidimensional structures into multidimensional databases into two kinds of tables. One kind is a fact table, which is used to storage the metric of fact and the code value of each dimension; the other kind is a dimension table. For each dimension, at least one table is used to store its data. The most popular multidimensional data models of data warehouses are star models and snow flake models. Dimension tables in a star framework can only generate relations with fact tables and no relation is generated among dimension tables. The property of snow flake models is to describe one complex dimension with several tables. It not only applies to the fact that people observe problems from multilayer perspective but also standardizes the dimension table of the star model. Since standard and lower granularity is adopted, the flexibility of application program is increased for snow flake models.

(2) Model Design

Data warehouse faces the subject. Generally speaking, the subject corresponds to the analytical object in certain analytical fields. The function of ESGS is to help people resolve incompatible problems, thus its subject is the incompatible problems concerned by decision makers. The design of ESGS model has its particularity. It considers the relevance tree of problems as the basis for model design. Take snow flake model for example here to illustrate.

Given the problem $P=G*L$, and its corresponding core problem is $P_0 = g_0 * l_0 = (Z_0, c_{0s}, X_0) * (Z_0, c_{0t}, c_{0t}(Z_0))$.

Suppose following initial correlation tree of problem can be got through relevance analysis:

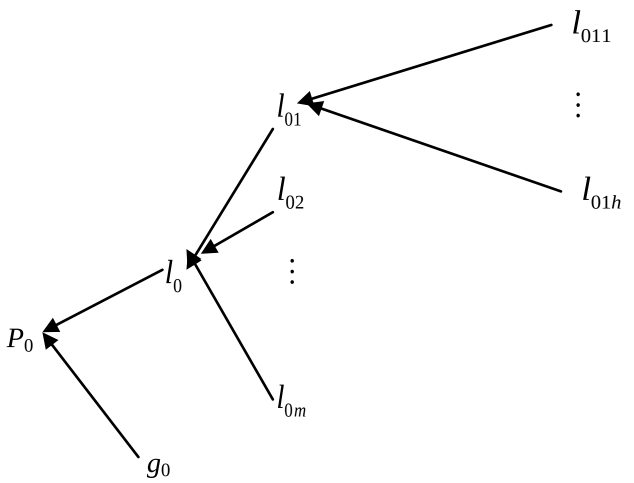


Figure 5.8 Initial Correlation Tree of Problem

1) Design of Fact Table

According to the properties of correlation tree and resolution features of incompatible problems, the corresponding initial relevance tree of the fact table is formed by roots and the sub-tree composed of a Level 1 node. It has two dimensions. One is the condition number and the other is the goal number. However, fact data is the value of dependent function *k*.

Table 5.5 Fact table

Problem No.
No. of goal dimension
No. of conditional dimension
Dependent function *k*

2) Design of Dimension Table

There are two kinds of dimension tables. One kind corresponds to the node which is neither root nor leaf; the other kind corresponds to the dimension table of leaf node. The conditional dimension table in Table 5.6 belongs to the first kind. See the other kind in Table 5.7.

Table 5.6 Conditional Dimension Table

Conditional dimension table
No. of conditional dimension
No. of L_{01} dimension
…
No. of L_{0m} dimension
Field of conditional dimension

Table 5.7 Dimension Table Corresponding to Leaf Node

L_{011} dimension table
No. of L_{011} dimension
L_{011} dimension field 1
L_{011} dimension filed 2

3. Design of data warehouse framework

This section will study how to generate one data warehouse needed by ESGS from one existing OLTP (online transaction processing) system.

(1) Establish the Foundation Base Adjustable to Core Problems

To study strategy generating technology, valuable information should be extracted from original mass base first according to the requirements of the core problem. Meanwhile, obtaining insufficient data information through survey, standardize existing data information by knowledge representation systems with the matter-element, affair-element and relation-element in Extenics as basic-elements and then express with the type of relational data table.

To facilitate the generation of fact tables and various dimension tables, the information of basic-element correlation should be add into the data table. Since the initial extension strategy spanning tree belongs to the directional tree and this correlation is manifested in parent-child membership, thus the information of parents can be increased in the data table with numbers. For instance, the parents of conditional node l_0 are problem node P_0 in initial correlation tree, thus the structure of its table is as follows:

Table 5.8 Conditional Data Table

Problem No.	Condition No.	Condition data 1	Condition data 2

Basic database is established on the basis of data table which can show basic-elements and their relation, as well as transformation and its operation.

(2) Design of Fact Table

For fact table 5.5, fact table can be generated with the statements below:

select *g*. problem number, *g*. goal number, *L*. condition number., dependent function *k*

from goal data table *g*, conditional data table *L*

where *g*. problem number =*L*. problem number

See corresponding data table in Table 5.9.

Table 5.9 Data Table Corresponding to Fact Table

Problem No.	Condition No.	Goal No.	Dependent function *k*

(3) Design of Dimension Table

For conditional dimension table 5.6, fact table can be generated with the statements below:

select *L*. condition number, *A*. L_{01} No., …, *M*. L_{0m} No., *L* condition. field

from conditional dimension table *L*, L_{01} dimension table *A*, …, L_{0m} dimension table *M*

where *L*. condition number =*A*. condition number AND

……

L. condition number =M. condition number

See corresponding data table in Table 5.10.

Table 5.10 Data Table Corresponding to Conditional Dimension Table

Condition No.	L_{01} No.	…	L_{0m} No.	Condition field

4. Generate extension strategies through extension transformation

(1) Seek for Basic Resolving Transformation of Problem

1) Extensible Reasoning or Conjugate Reasoning

In the initial correlation tree, the extension of problems refers to the extension of "leaf" basic-elements through extensible reasoning. Divergent reasoning or opening-up reasoning can be adopted. However, conjugate reasoning can only be used when the "leaf" basic-elements in the initial correlation tree are matter-elements.

For the initial correlation tree above, suppose its set of "leaf" basic-elements as {l_{011} , …, l_{01h},…}, only the divergent reasoning of "one characteristic with several measures" is selected as example below to illustrate:

Given basic-element l=（Γ, c, v）, thus:

$$l \dashv \{l_i \mid l_i = (\Gamma, c, v_i),\ i=1, 2, \dots, n\}$$

See the rest extensible reasoning rules in 2.8 of this book.

Now take l_{01h} for example, since l_{01h} corresponds to one dimension data table as shown in Table 5.11:

Table 5.11 L_{01h} Dimension Table

L_{01h} No.	Feature c_{01k}

Suppose the initial value as (c_{01k}, v_{01k}), then extensible reasoning can be realized with the statements below:

insert into extensible data table

select L_{01h} No., feature c_{01h}

from L_{01h} dimension table

Where c_{01h}<>v_{01h}

2) Make the conductive transformation of basic-element transformation

Supposing the primal problem is an incompatible problem, conductive reasoning of basic-element transformation needs to be made after correlation analysis of the basic-element.

Make $\varphi l_{01h} = l_{01h}'$. Since conductive effect will cause a series of transformations and finally lead to the transformation of l_0, it makes the dependent degree of the problem change. See its problem correlation tree about extension transformation φ in Figure 5.9.

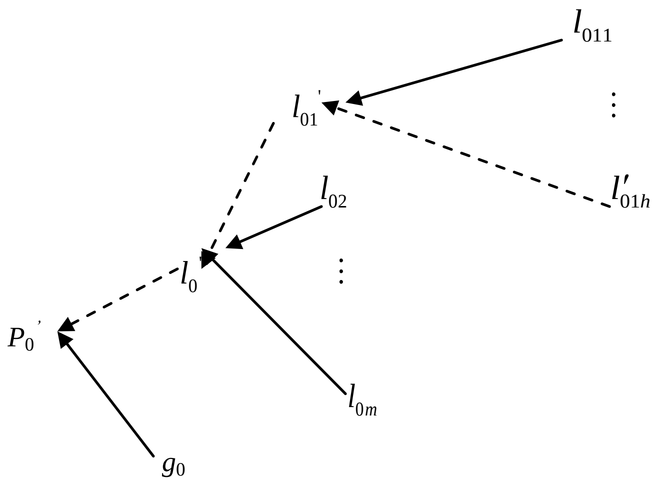


Figure 5.9 Problem Correlation Tree about Active Transformation φ

This kind of conductive transformation of basic-element transformation can be realized with the statements below:

select *F*. problem number, *F*. condition number, $A.l_{01}$ No., $B.l_{01h}$ No., *F*. dependent function *k*

from, fact table *F*, L_0 dimension table *L*, L_{01} dimension table *A*, L_{01h} dimension table *B*

Where *F*. condition number =*L*. condition number AND

$L.L_{01}$ No. =$A.L_{01}$ No. AND

$A.L_{01h}$ No. =$B.L_{01h}$ No. AND

$c_{01h}(l_{01h}') = v_{01h}'$

If the value of dependent function $k>0$, extension transformation φ is the resolving transformation of incompatible problems, i.e. extension strategies.

The dynamic change table of corresponding problem is:

Table 5.12 Dynamic Change Table Before and After Implementing Transformation φ

Dependent function value	G_0 No.	L_0 No.	L_{01} No.	L_{01h} No.	State
$k(P_0)$	g_0	l_0	l_{01}	l_{01h}	Initial state
$k({}_{l_0}T_{P_0})$	g_0	l_0'	l_{01}'	l_{01h}'	After transformation

If there is no resolving transformation in all basic transformations, then make transformations' operation.

(2) Make Transformations' Operation

The operation of transformations includes AND transformation, OR transformation, product transformation and inverse transformation.

Make extensible reasoning first and then take AND transformation of two basic transformations for example. The basic idea is: select two basic-elements l_i and l_j to make the operation of extensible reasoning:

Set $(l_i \wedge l_j)\dashv = (l_i\dashv) \wedge (l_j\dashv)$ =H, select the basic-element which makes dependent function value k>0, set

$$HW \subseteq H, HW = \{l_{i_1}, \cdots, l_{i_m}\}, \quad m \le h$$

Then there are accordingly m extension transformations ***T***=$\{T_1, T_2, \ldots, T_m\}$. If T is non-empty, a strategy set is generated; if ***T*** is empty for all l_i and l_j, there is no strategies composed of AND transformation of two basic transformations for this problem.

For instance, for the initial problem correlation tree below:

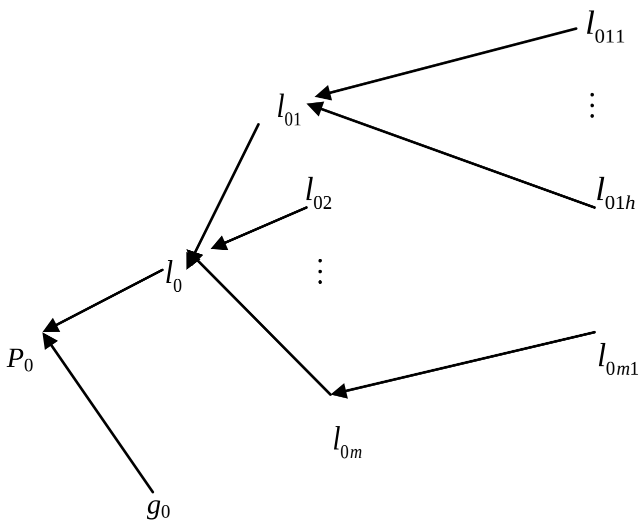
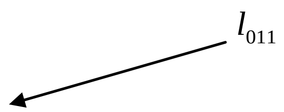


Figure 5.10 Initial Correlation Tree of Problem

Make transformation: $\varphi\, l_{01h} = l_{01h}{'}$, $\tau l_{0m1} = l_{0m1}{'}$, let $T = \varphi \wedge \tau$, i.e. make AND transformation of two transformations. The problem's correlation tree after transformations is as follows:



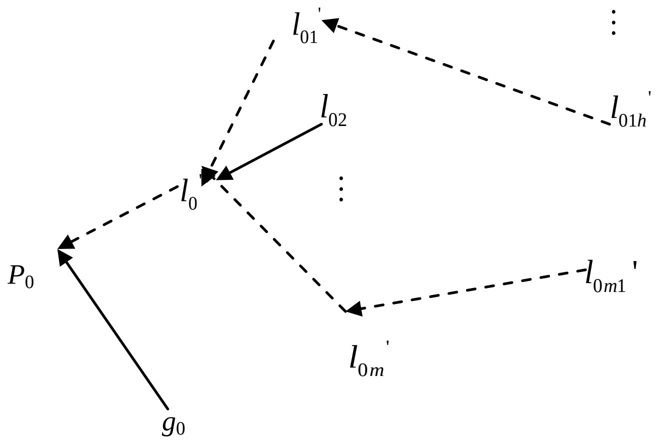


Figure 5.11 Problem's Correlation Tree about the Operation $T=\varphi\wedge\tau$ of Active Transformations

The conductive transformation of this kind of basic-element transformations can be realized with the statements below:

select *F*. problem number, *F*. condition number, $A.L_{01}$ No., $B.L_{01h}$ No., $C.L_{0m}$ No., $D.L_{0m1}$ No. *F*. dependent function k

from, fact table *F*, L_0 conditional dimension table *L*, L_{01} dimension table *A*, L_{01h} dimension table *B*, L_{0m} dimension table *C*, L_{0m1} dimension table *D*

Where *F*. condition number =*L*. condition number AND

$L.l_{01}$ No. =$A.l_{01}$ No. AND

$A.l_{01h}$ No.=$B.l_{01h}$. No.

$L.l_{0m}$ No.=$C.l_{0m}$ No. AND

$C.l_{0m1}$ No.=$D.l_{0m1}$. No. AND

$c_{01h}(l_{01h}')=v_{01h}'$ AND

$c_{0m1}(l_{0m1}')=v_{0m1}'$

If dependent function value *k*>0, extension transformation *T* is the resolving transformation of incompatible problem, i.e. extension strategies.

The dynamic change tale of corresponding problem is:

Table 5.13 Dynamic Change Table Before and After Implementing Transformation *T*

Dependent function value	G_0No.	L_0 No.	L_{01} No.	L_{01h} No.	L_{0m} No.	L_{0m1} No.	State
$k(P_0)$	g_0	l_0	l_{01}	l_{01h}	l_{0m}	l_{0m1}	Initial state
$k(_{l_0}T_{P_0})$	g_0	$l_0^{'}$	$l_{01}^{'}$	$l_{01h}^{'}$	$l_{0m}^{'}$	$l_{0m1}^{'}$	After transformation

5.2.5 Functional Module of ESGS

Main functional modules of ESGS include: basic database, extension rule base, problem base, extension transformation base and extension strategy base.

1. Basic database

It has been clearly pointed out in 5.2.4 that this section is only limited to the study of ESGS based on database and data warehouse technologies. Besides, the technology adopted belongs to relational data warehouse. It storages the data in data warehouse into the table structure of relational database, which is also called ROLAP.

The key to realizing the technology based on a relational database is how to express multidimensional concept with the two dimensional tables in a relational database, i.e. dividing the multidimensional structure in a relational database into two kinds of tables. One kind is fact table and the other kind is dimension table. For generating a data warehouse required by ESGS from one existing OLTP (online transaction processing), basic database serves as a bridge. We request to establish a basic base adjustable to core problem and strategies. The establishment of basic base takes two steps. The first step is to express information with basic-elements and express knowledge with various relations of basic-elements. The second step is to establish the basic database.

To study strategy generation, we need to extract valuable information from original mass data first. Meanwhile, we must obtain insufficient data information through survey and standardize the existing data information with the basic-element information and knowledge representation system in Extenics. That is, present concept class and entity with basic-elements, including: present matters with matter-elements, present affair with affair-elements, and present the relation among objects with relation-elements; the goal class basic-element of problem and corresponding instance basic-element; the condition class basic-element of problem and corresponding instance basic-element; and basic-elements with various classes relating to conditions and corresponding instance basic-elements etc. Present matter-element, affair-element and relation-element with relational data tables. The data table should also reflect the properties of strategy tree. One common method is to increase the codes of parents in data table. For instance, the data table of matter-element is shown in Table 5.1. The data table reflecting extension transformation is shown in table 5.4.

Reference [20] introduces how to present basic-elements with data table in detail. The details about the way to establish basic base isn't given here.

2. Extension rule base

The rules included in extension rule base are generally classified into two kinds: one kind refers to rules offered by Extenics. They possess common properties. That is, these rules can be used by all those presented by basic-elements in form, which has nothing to do with details. Such as, extension reasoning rules, dependent function formulas and superiority evaluation rules. The other kind aims at relevant rules of details and corresponding implication rules of transformations. They are important tools for finding problems, analyzing problems and generating strategies.

Extension reasoning rules include the extensible reasoning rules of basic-elements, conductive reasoning of basic-element transformation and conjugation reasoning rules. Technically speaking, they can be presented with data tables as well as production rules. For convenient access, some of them need to be specially programmed.

Rule base also includes dependent functions in various types, e.g. primary dependent function, simple dependent function, interval dependent function and discrete dependent function. Dependent functions in different types have distinct ranges of application. To improve the quality of each system, proper dependent function formula should be selected for concrete problems.

Superiority evaluation rules are the basic norms for evaluating the superiority of one object, including things, strategies, programs and ideas etc. They are mainly used for the evaluation and selection of strategies and programs in this book.

Technically speaking, the degree of universality of extension rule base should be improved as much as possible. They can be put on the server in multi-layer structure.

In many practical problems, lots of rules or knowledge is unknown, which needs to be obtained through extension data mining. See details in 5.3 of this book.

3. Problem base

Problem base can be composed of an early warning problem base, a surface problem base and a deep problem base.

Put vital problems or those needing to be resolved immediately in early warning problem base to make sure they can attract people’s enough attention through various measures. Proper signs need to be adopted technically, e.g. red color, black frame, exclamation mark or some other special icons are used.

Starting from the information in basic base, establish rules with dependent functions of different types in rule base. For different indexes, distinct dependent functions and threshold values are selected so as to find problems and then put them in surface problem base.

To resolve incompatible problems, the problems in surface problem base must be analyzed to fine their roots—deep problems, and then put them in deep problem base.

Technically speaking, data table, statistical graphics or some special statistical decision components are required to be adopted as much as possible so as to make sure the users can observe and find problems from different perspective (including different layers and granularities) and supply friendly interface.

Deep problems are storage in deep problem base, which originates from the extensible analysis of surface problems. To solve problems, extensible analysis must be made for surface problems so as to find their roots—deep problems. Then “suit the remedy to the case” to solve the problems. The tools for making deep analysis of problems should be provided technically. For instance, the use of tree-structure components which can make implication analysis as well as special data warehouse components and other visible tools which can make multi-layer analysis facilitate the users to analyze problems with extension methods.

4. Extension transformation base

Extension transformation is the basic technology for generating strategies. Through extension transformation, unknown problems among those seek for solutions can be changed to knowable ones, and infeasible problems among those seek for feasibility can be changed to feasible ones.

Extension transformation base includes basic transformation, transformations' operation formula and conductive transformation (including conjugation transformation). Based on different transformation objects, they can also be embodied as element's transformation, transformation of dependent criterion and transformation of universe of discourse. See more details in corresponding contents of reference [6] and [20].

According to the universe of discourse, dependent criterions and basic-elements involved in problem base, various extension possibilities of them can be obtained through extensible analysis. Then based on basic transformation, transformations' operation formula or conductive transformation, various extension strategies can be generated.

Technically speaking, extension transformation can be presented with a data table, production rules or extension transformation diagrams. The transformation has something to do with the details of universe of discourse, thus it is dynamic. Some transformations can be given first according to the problems and then relevant transformations can be constantly generated in the process of solving problems.

Extension transformations all correspond to corresponding data tables as shown in Table 5.14 and 5.15.

There are several one-order conductive transformations and multiple-order conductive transformations in Table 5.14 and 5.15, which are omitted in the table.

Table 5.14 Table of Basic Transformations

Name of active transformation	Transformation object	Result	One-level conductive transformation

Table 5.15 Table of Transformations' Operation Formulas

Transformation name	Operation type	Active transformation 1	Active transformation 2	…	Transformation object	Result	One-level conductive transformation	Multiple-level conductive transformation

5. Extension strategy base

For the study of strategy generation, there are two feasible ideas now:

(1) Based on special knowledge (or called field knowledge), analyze basic database with extension methods to find incompatible problems and put them in "problem base". Then confirm material deep problems through extension reasoning rules and human-machine dialogues. Transform the goal or conditions of problems through the transformations in "extension transformation base". Among all implemented transformations, make those which can change the compatibility of problem from <=0 to >0 as the resolving transformations of incompatible problems. In Extenics, these resolving transformations are called the extension strategies for resolving incompatible problems. For all generated extension strategies, evaluate them with superiority evaluation rules to get the superiority of each extension strategy and provide reference for decision makers.

(2) Directly generate correlation rules from basic database with extension data mining methods and form basic rule base. Then obtain problem rule base, strong correlation rule base and optimized rule base according to dependent function and threshold value. For problems selected from problem base, generate resolution

strategies through extension transformation and make evaluation and optimum through case base.

Put the extension strategies generated with above two ideas in extension strategy base. The common representation is production rule. Storage in file form or divide into numerous windows as required to respectively presenting the resolution strategies of different problems.

This section only makes a simple introduction of the functional module of ESGS. Detailed implication cases are supplied in reference [20] for interested readers.

5.3 Extension Data Mining Method

Extension data mining [21-24] is the product of the combination of Extenics and data mining, which studies the mining of the knowledge relevant to the contradictory problem's solving transformations from the database by using the theories and methods of Extenics. This section introduces the mining of transformation-based knowledge accumulated in the database or knowledge base in various fields by using the basic theories and methods of Extenics, referred to as the extension knowledge for short.

5.3.1 Significance and Value of the Study

The implementation of any major policy will influence the social and economic development, and consequently change the statistical data; on the contrary, the policy functioning laws can be mined from the social and economic statistics database. In many trades, people have to consider what correlations exist between the various characteristics of the object and between different study objects, what transformation should be adopted to solve contradictory problems, and what effect will be generated after implementing certain transformation, etc. For example, at economic overheating or recession, the banks treat the problems by raising or reducing the interest. Then, can we know the function and effect of these transformations, so as to gain certain awareness of the changed data, range and affecting speed? On the contrary, can the relevant knowledge on these transformations be found from the previous database and the large amount of accumulated data to help the corresponding decision making in the future? For example, when to raise the interest as appropriate, and how about its range, etc. These problems can be found everywhere.

On the other hand, for the computer to have a higher intelligence level, we must study the theory and methods to generate the contradictory problem solving strategy, and the laws and technology of intelligent contradictory problem processing. Since the key to solve contradictory problems is transformations, we must study how to find the transformations, analyze the transformations' functions, and acquire the knowledge relevant to the functions of transformations on data change from databases, to provide the basis to generate the contradictory problem's processing strategies.

Based on the above two reasons, people must study the new data mining theory and methods that are suitable for the data changing laws under transformations.

With the rapid development of computer software and hardware technology, various industries have established their own databases, and the collected data has been doubled each year. The rich knowledge hidden in the tremendous accumulated data can be used to provide guidance and help for future works. Nevertheless, given such a large amount of data and rapid growth rate, it will be completely ineffective to acquire the potential knowledge by manual analysis. Data mining, as a key technology in IT development, has produced significant values in marketing.

However, the existing data mining theory and methods concerns the mining of knowledge under unchanged conditions, and there is still no relevant study to find the laws that lead to data change in the tremendous data.

Extenics studies the laws and methods to process contradictory problems through transformations, and its set theory basis is the extension set theory. From the viewpoint of extension set, an item in the database is an n-dimensional basic-element, and a datasheet is a basic-element domain. It can calculate the correlativity between the data and the item by the dependent function, to express the degree to which an object meets a certain requirement, study the laws that transformation acts on data by the extension rule, and determines the transformation source and implication of extension transformations by the nature and operation of dependent function and extension set, through extension reasoning.

Extension data mining theoretically applies the extension set theory and extension logic in data mining, corresponds the database and data warehouse to the extension set's universe of discourse, and corresponds the data to the basic-elements, consequently combines the extension set theory with data mining, to form the basic theory to mine the “extension knowledge”. In terms of methodology, it combines the formalization system with basic-elements as logical cells with the database and data warehouse, to form the knowledge representation suitable for data “transformation”, and uses the extension reasoning and dependent function as tools to establish a set of extension data mining methods that are suitable for extension knowledge mining, and further develops the experimental software of obtaining “extension knowledge”.

It's a valuable ground-breaking work to combine the extension theory and methods that solve contradictory problems by formalized model with data mining technology, mine the “extension knowledge” and “transformation's functions” from the database or knowledge base by extension method, and consequently to mine the laws by which the data is changed with the change of policy (described by the formalization of extension transformations) from database, and the laws by which the knowledge is changed under the transformation's functions from knowledge base, so as to provide the reference basis for decision making. It has certain scientific significance in developing the data mining theory and method, and more practical values in finding the problem solving strategies and analyzing the transformation's functions in the various economic industries (such as finance, taxation, and real estate, etc.).

It's shown by studies that the existing data mining theory and technology will be developed and new data mining theory and technology will be generated by the combination of Extenics and data mining. The application of this technology in the study on the data mining in the fields of marketing, customer relations management, finance and securities, telecommunication, and medical treatment, etc., will provide effective decision supports to solve the contradictory problems in the marketing process.

5.3.2 Main Methods of Extension Data Mining

Up to now, we have studied the basic theory and methods, and computer implementation of extension data mining. In this section, we'll briefly introduce the main study results of the extension data mining methods, including the database based extension classification knowledge mining method, database based conductive knowledge mining method, database based extension clustering knowledge method, and the knowledge base based extension knowledge mining method, for details see the reference [21]and [22].

1. Database based extension classification knowledge mining method

Extension classification is the classification on the basis of extension transformation, with extension set as its set theory basis. It significantly differs from the classification method based on classical set. For example, when an enterprise classifies its customers by priority, they can be classified into “important customers” and “non-important customers” by using the classification method based on classical set. But actually, among the “non-important customers”, some can be transformed to the “important customers” through certain transformations; in the same way, among the “important customers”, some customers can be transformed to the “non-important customers” through certain transformations. It's obvious that the classification under such transformations depends on the adopted transformations themselves, with different transformations corresponding to different classifications. Such classification problems are found abundantly in the real world, so these transformation-based classification methods must be studied.

According to the definition of extension set, a given extension transformation corresponds to a classification of the extension set that can divide it into five parts of positive qualitative change field, negative qualitative change field, positive quantitative change field, negative quantitative change field and extension boundary, corresponding to the extension transformation of the elements in the universe of discourse that also divides the universe of discourse into five parts. Such classification method based on extension set is referred to as the extension classification method.

It can be seen that the extension classification method is based on the extension transformation, including the extension classification based on the transformation of elements in the universe of discourse, the extension classification based on the transformation of dependent criterion, and the extension classification based on the transformation of the universe of discourse.

(1) Meaning of Extension Classification Knowledge

Extension classification is the classification under transformation, which divides the universe of discourse U into the following five fields (the following signs can be seen in section 2.6 of this book):

Positive extension field (also referred to as positive qualitative change field) $\underset{\cdot}{E}_{+}\left(T\right)$;

Negative extension field (also referred to as negative qualitative change field) $\underset{\cdot}{E}_{-}\left(T\right)$;

Positive stable field (also referred to as positive quantitative change field) $E_{+}\left(T\right)$;

Negative stable field (also referred to as negative quantitative change field) $E_{-}\left(T\right)$;

Extension boundary $E_0(T)$.

We should study to find the following knowledge from the databases:

1) Extension Classification Knowledge on Positive Qualitative Change:

Under transformation T, what kind of information element I has $I \in \underset{\cdot}{E}_{+}\left(T\right)$, i.e. the information element with what characteristics will be transformed from not belonging to the positive field to belonging to the positive field after implementation of transformation T? In the above case, we can find the customer with what characteristics can be transformed from not being the shop's customer to being the shop's customer after the implementation of the "midnight consumption" campaign, and also investigate what commodities are transformed from being unmarketable to popular, etc.

2) Extension Classification Knowledge on Negative Qualitative Change:

Under transformation T, what kind of information element I has $I \in \underset{\cdot}{E}_{-}\left(T\right)$, i.e. the information element with what characteristics will be transformed from not belonging to the negative field to belonging to the negative field after implementation of transformation T? In the above case, we can find the customer with what characteristics can be transformed from being the shop's customer to not being the shop's customer after the implementation of the "midnight consumption" campaign, and also investigate what commodities are transformed from being popular to unmarketable, etc.

3) Extension Classification Knowledge on Positive Quantitative Change:

Under transformation T, what kind of information element I has $I \in E_{+}\left(T\right)$, i.e. the information element with what characteristics that belonged to the positive field and still belongs to the positive field after the implementation of transformation *T*. In the above case, we can find the customer with what characteristics is still the shop's customer after the implementation of the "midnight consumption" campaign, and also investigate what commodities those were popular and are still popular, etc.

4) Extension Classification Knowledge on Negative Quantitative Change:

Under transformation *T*, what kind of information element *I* has $I \in E_-(T)$, i.e. the information element with what characteristics that belonged to the negative field and still belongs to the negative field after the implementation of transformation *T*. In the above case, we can find the customer with what characteristics is still not the shop's customer after the implementation of the "midnight consumption" campaign, and also investigate what commodities those were unmarketable and are still unmarketable, etc.

5) Extension Classification Knowledge on Extension Boundary:

Under transformation *T*, what kind of information element *I* has $I \in E_0(T)$, i.e. the information element with what characteristics will become the information element in extension boundary, including the information elements transformed to the extension boundary from the positive field, the negative field and the zero boundary?

For the above knowledge, the representation of extension classification knowledge can be given according to the previous introduced definition of extension set and the implicative representation of knowledge.

(2) Support and Confidence

The rule knowledge is obtained by data mining from a batch of data, and its correctness is measured by support and confidence.

The support indicates the percentage of the cases (element set) represented by the rule in the total cases (element set), such as the percentage of the customers that buy both bread and milk in the total customers.

The confidence indicates the percentage of the cases represented by the rule in the cases that meet the precondition, for example, if the customers that buy both bread and milk take up 90% of the customers that buy bread, we say the confidence is 90%.

In the knowledge equation, the support and confidence are usually expressed as

$$\ell = (\text{support，confidence}) = (\text{support,confidence})$$

i.e. the knowledge equation, is denoted as : $A \Rightarrow (\ell)B$.

(3) Representation of Extension Classification Knowledge and Calculation Method of Its Support and Confidence

Suppose U is universe of discourse, $u \in U$, k is a mapping of U to real field, and *T* is extension transformation, as to the extension set of the transformation *T* of elements in the universe of discourse

$$\tilde{E}(T) = \{(u, y, y') | u \in U, y = k(u) \in \Re; Tu \in U, y' = k(Tu) \in \Re\}$$

when $T=e$, U is divided into three fields E_+, E_-, E_0; when $T \neq e$, T divides U into five fields $\underset{\cdot}{E}_+(T)$, $\underset{\cdot}{E}_-(T)$, $E_+(T)$, $E_-(T)$, $E_0(T)$;

1) Knowledge on Positive Qualitative Change:

If when $u \in E_- \cup E_0$, under transformation *T*, there is $u \in \underset{\cdot}{E}_+(T)$, we call it the knowledge on positive qualitative change of u produced under transformation *T*, denoted by

$$(Tu = u') \wedge (u \in E_- \cup E_0) \Rightarrow (\ell_1)(u \in \underset{\cdot}{E}_+(T))$$

wherein ℓ_1 indicates the support and confidence of this piece of knowledge: the support is the percentage that the sum $|E_-|+|E_0|$ of the objects in the negative field and zero boundary takes up in the number of all objects $|U|$ in the universe of discourse; the confidence is the percentage that the number $|\underset{\cdot}{E}_+(T)|$ of the objects transformed from negative field or zero boundary into positive field takes up in the sum $|E_-|+|E_0|$ of the objects in negative field and zero boundary, i.e.

$$\ell_1 = \left(\frac{|E_-|+|E_0|}{|U|}, \quad \frac{|\underset{\cdot}{E}_+(T)|}{|E_-|+|E_0|} \right)$$

For example, the universe of discourse of the customers group of a certain telecom service department of a telecom company in a certain region is *U*, and it can be known from market survey and the enterprise historical data that there are 100,000 users who use or used the telecom service in the region, i.e. $|U|$=100,000 (people), within which, there are 50,000 users who still use the telecom service of the company (current users), i.e. $|E_+|$ =50,000 (people), and there are 3,000 frozen users, i.e. $|E_0|$=3,000 (people). It's obvious that the number of lost customers is $|E_-|$=47,000 (people). (Note: the universe of discourse is presumed unchanged in this case.)

To benefit the old customers and attract new customers, the service department adopts a promoting activity of "free mobile phones for deposit of telephone expenses), i.e. adopts the transformation *T*="free mobile phone for deposit of telephone expenses", transformed partial loosing or frozen customers to the company's current customers. After the activity, these customers are 20,000 people according to statistics, i.e. $|\underset{\cdot}{E}_+(T)|$=20,000 (people). We can obtain the knowledge: by adopting "free mobile phone for deposit of telephone expenses", a batch of "lost customers" or "frozen" customers can be transformed to the enterprise's current customers, with the support and confidence as

$$\ell_1 = \left(\frac{|E_-|+|E_0|}{|U|}, \quad \frac{|\underset{\cdot}{E}_+(T)|}{|E_-|+|E_0|} \right) = \left(\frac{4.7+0.3}{10}, \quad \frac{2}{4.7+0.3} \right) = (0.5, \quad 0.4)$$

On this basis, the company can summarize the experience and discover knowledge, to provide reference to design marketing activities and determine the goal customers in the future.

2) Knowledge on Negative Qualitative Change:

If when $u \in E_+ \cup E_0$, under transformation *T*, there is $u \in \underset{\cdot}{E}_-(T)$, we call it the knowledge on negative qualitative change of u produced under transformation *T*, denoted by

$$(Tu = u') \wedge (u \in E_+ \cup E_0) \Rightarrow (\ell_2)(u \in \underset{\cdot}{E}_-(T))$$

wherein ℓ_2 indicates the support and confidence of this piece of knowledge: the support is the percentage that the sum $|E_-|+|E_0|$ of the objects in the positive field and zero boundary takes up in the number of all objects $|U|$ in the universe of discourse; the confidence is the percentage that the number $|\underset{\cdot}{E}_-(T)|$ of the objects transformed from positive field or zero boundary into negative field takes up in the sum $|E_+|+|E_0|$ of the objects in positive field and zero boundary, i.e.

$$\ell_2 = \left(\frac{|E_+|+|E_0|}{|U|}, \quad \frac{|\underset{\cdot}{E}_-(T)|}{|E_+|+|E_0|} \right)$$

In the above case, if transformation *T* is implemented to let the current or frozen customers to no longer use the service, with the number of 2000 people, i.e. $|\underset{\cdot}{E}_-(T)|$=2,000 (people), then we can obtain the knowledge on what type of customers (or customers under what conditions) can be transformed from the "current customers' or "frozen customers" to "lost customers" through this transformation, with the support and confidence as

$$\ell_2 = \left(\frac{|E_+|+|E_0|}{|U|}, \quad \frac{|\underset{\cdot}{E}_-(T)|}{|E_+|+|E_0|} \right) = \left(\frac{5.3}{10}, \quad \frac{0.2}{5.3} \right) = (0.53, \quad 0.04)$$

3) Knowledge on Positive Quantitative Change:

If when $u \in E_+$, under transformation *T*, there is $u \in E_+(T)$, we call it the knowledge on positive quantitative change of u produced under transformation *T*, denoted by

$$(Tu = u') \wedge (u \in E_+) \Rightarrow (\ell_3)(u \in E_+(T))$$

wherein ℓ_3 indicates the support and confidence of this piece of knowledge: the support is the percentage that the number $|E_+|$ of the objects in the positive field takes up in the number of all objects $|U|$ in the universe of discourse; the confidence is the percentage that the number $|E_+(T)|$ of the objects that are still in the positive field after transformation takes up in the number $|E_+|$ of the objects in the positive field, i.e.

$$\ell_3 = \left(\frac{|E_+|}{|U|}, \quad \frac{|E_+(T)|}{|E_+|} \right)$$

In the above case, if under the implementation of transformation *T*, some "current customers" are still "current customers", with the number of 49,000 people, i.e. $|E_+(T)|$=49,000 (people), then we can obtain the knowledge on what type of customers (or customers under what conditions) can remain the "current customers" through this transformation, with the support and confidence as

$$\ell_3 = \left(\frac{|E_+|}{|U|}, \quad \frac{|E_+(T)|}{|E_+|} \right) = \left(\frac{5}{10}, \quad \frac{4.9}{5} \right) = (0.5, \quad 0.98)$$

4) Knowledge on Negative Quantitative Change:

If when $u \in E_-$, under transformation *T*, there is $u \in E_-(T)$, we call it the knowledge on negative quantitative change of u produced under transformation *T*, denoted by

$$(Tu = u') \wedge (u \in E_-) \Rightarrow (\ell_4)(u \in E_-(T))$$

wherein ℓ_4 indicates the support and confidence of this piece of knowledge: the support is the percentage that the number $|E_-|$ of the objects in the negative field takes up in the number of all objects $|U|$ in the universe of discourse; the confidence is the percentage that the number $|E_-(T)|$ of the objects that are still in the negative field after transformation takes up in the number $|E_-|$ of the objects in the negative field, i.e.

$$\ell_4 = \left(\frac{|E_-|}{|U|}, \quad \frac{|E_-(T)|}{|E_-|} \right)$$

In the above case, if under transformation *T*, some "lost customers" are still "lost customers", with the number of 26,000 people, i.e. $|E_-(T)|$=26,000 (people), then we can obtain the knowledge on that the adaptation of "free mobile phone for deposit of telephone expenses" can let a batch of "lost customers" remain the "los customers", with support and confidence as

$$\ell_4 = \left(\frac{|E_-|}{|U|}, \quad \frac{|E_-(T)|}{|E_-|} \right) = \left(\frac{4.7}{10}, \quad \frac{2.6}{4.7} \right) = (0.47, \quad 0.55)$$

5) Knowledge on Extension Boundary:

If when $u \in E_+ \cup E_0 \cup E_-$, under transformation *T*, there is $u \in E_0(T)$, we call it the knowledge on that u belongs to extension boundary under transformation *T*, denoted by

$$(Tu = u') \wedge (u \ni L_5) \Rightarrow (\ell_5)(u \in E_0(T))$$

wherein ℓ_5 indicates the support and confidence of this piece of knowledge. This piece of knowledge has three types:

① Knowledge of transformation from a positive field to an extension boundary, with its knowledge equation expressed by:

$$(Tu = u') \wedge (u \in E_+) \Rightarrow (\ell_{+5})(u \in E_{+0}(T))$$

② Knowledge on transformation from a negative field to an extension boundary, with its knowledge equation expressed by:

$$(Tu = u') \wedge (u \in E_-) \Rightarrow (\ell_{-5})(u \in E_{-0}(T))$$

③ Knowledge on transformation from a zero boundary to an extension boundary, with its knowledge equation expressed by:

$$(Tu = u') \wedge (u \in E_0) \Rightarrow (\ell_{05})(u \in E_{00}(T))$$

Different types have different calculation methods of its support and confidence, and the following can be given by referencing the above types:

$$\ell_{+5} = \left(\frac{|E_+|}{|U|}, \quad \frac{|E_{+0}(T)|}{|E_+|} \right)$$

$$\ell_{-5} = \left(\frac{|E_-|}{|U|}, \quad \frac{|E_{-0}(T)|}{|E_-|} \right)$$

$$\ell_{05} = \left(\frac{|E_0|}{|U|}, \quad \frac{|E_{00}(T)|}{|E_0|} \right)$$

In the above case, if under transformation *T*, some “current customers” are transformed to “frozen customers”, with the number of 2,000 people, i.e. $|E_{+0}(T)|$=2,000 (people), we can obtain the knowledge on what type of customers (or the costumers under what conditions) can be transformed from “current customers” to “frozen customers” through this transformation, with support and confidence as

$$\ell_{+5} = \left(\frac{|E_+|}{|U|}, \quad \frac{|E_{+0}(T)|}{|E_+|} \right) = \left(\frac{5}{10}, \quad \frac{0.2}{5} \right) = (0.5, \quad 0.04)$$

In this case, the “lost customers” cannot be transformed to “frozen customers”, so there is no second type of knowledge on extension boundary. If under transformation *T*, some “frozen customers” remain “frozen customers”, with the number of 1,000 people, i.e. $|E_{00}(T)|$=1,000 (people), we can obtain the knowledge on what type of customers (the customers under what conditions) can remain “frozen customers” through this transformation, with support and confidence as

$$\ell_{+5} = \left(\frac{|E_0|}{|U|}, \quad \frac{|E_{00}(T)|}{|E_0|} \right) = \left(\frac{0.3}{10}, \quad \frac{0.1}{0.3} \right) = (0.03, \quad 0.33)$$

The above five types of knowledge are collectively called extension classification knowledge.

(4) Extension Classification Knowledge Mining Methods

It can be seen from the extension classification knowledge introduced above that it's changing classification knowledge with different results according to different transformations. This is the very important knowledge that the enterprise can mine from the databases to discover the functions and effects of the implemented or naturally appeared transformations, as reference for future decision making.

General steps of extension classification knowledge mining from databases:

1) Select the evaluation characteristics according to the enterprise situation and professional theory;
2) List the original characteristics that exist in the original data table and correspond to the evaluation characteristics;
3) Obtain the measures of evaluation characteristics and accordingly obtain the evaluation information element table;
4) Determine the evaluation rule for each evaluation characteristic according to the actual situation of the enterprise, to establish dependent function and obtain the dependent degree table of evaluation information elements;
5) Determine the construction method of comprehensive dependent function according to extension set theory and professional knowledge, and specify the classification rule, to obtain the static classification knowledge;
6) Obtain the evaluation information element table after extension transformations;
7) According to the dependent function established in 4), obtain the dependent degree table of evaluation information elements after extension transformations;
8) Recalculate the comprehensive dependent degree after the transformation;
9) Obtain the extension classification knowledge according to the extension classification methods and the comprehensive dependent degree values before and after the transformation.

2. Database based Conductive knowledge mining methods

In Chapter 2 of this book, we introduced the concept of conductive transformations, from which we know that because of the various correlations between the objects, a transformation cannot only lead to the change of its functioned object, but also lead to the change of its correlated objects due to the conductive function, and the former transformation is called active transformation while the transformation of the latter is called conductive transformation of the former.

These conductive transformations that are reflected in databases are the changes of the information elements that are related to their functioned objects. Some of these changes are positive, helpful for decision-makers to treat contradictory problems; some are negative, affecting the decision-makers in treating contradictory problems, or generating new contradictory problems; some lead to beneficial cycles while some lead to vicious cycles. If the conductive knowledge on these conductive transformations can be mined from the existing database, they can serve as the basis for decision-makers to utilize the positive function of conductive transformations and prevent the negative function of conductive transformations.

For example, an investment company plans to sell its payment service system by auction because the service system has been losing money. But it's verified by survey and analysis that the majority of the company's loyal and lucrative customers are using the payment service system. Although the payment service system is losing money, the company can make considerable money from other accounts of these customers. After all, the customers trust their financial institution and allow it to help their bill payments, and the institution has high credit worthiness among these customers. Therefore, it's considered by the company not to cut such added-value service project, for such doing may let the best customers look for better services elsewhere, and intentionally decrease the company income. In other words, from the viewpoint of conductive transformations, if the company makes the active transformation of "selling the payment service system by auction", it will inevitably cause the occurrence of the conductive transformation of "losing the best customers". Through data mining, this transformation knowledge can be found to reduce the company loss. This knowledge is obviously valuable to the company decision-makers.

The change of the communication measure by which an insurance company contacts with its customers will lead to a cost reduction. For example, the notice on payment and payment receipt, and introduction to new business which were formerly provided by the insurance company to its customers in form of correspondence, with low contact speed and high cost, and now are provided in the form of SMS prompt, except for the payment invoice is mailed, with fast speed and low cost. It's certain that the insurance company wants to know what type of customers likes this new form and accordingly wants to buy more insurance, and what type of customers doesn't like this form and accordingly complains the service quality or claims cancellation of insurance. It can be seen that this knowledge is very important for the insurance company. To acquire such knowledge, the insurance company can implement different contact methods for different customer groups, to maintain more customers.

(1) Conductive Knowledge and Its Types

Conductive knowledge is the knowledge based on conductive transformation. In a database, the transformation used on certain data will also cause transformations of correlated data. From the data before and after the change, we can obtain the knowledge on what objects undergo the conductive transformation (conductive objects), what characteristics undergo the conductive transformation (transformation characteristics), how about the conductive effect (conductive effect), and what about the conductive degree (conductive degree), etc. which are collectively called conductive knowledge.

In case of transformations implemented on an information element, it's correlated knowledge and strategies will change with it, the knowledge on changes produced by the occurrence of conductive transformations is called conductive knowledge, which includes the following types:

1) Knowledge on Conductive Objects and Conductive Characteristics

A transformation will change the measures of its affected object about certain characteristics, but have no effect on the measures about other characteristics. Then, what characteristics can be affected, and what about the degree of the effect: A transformation will generate conductive effect on certain objects, but generate no conductive effect on other objects. Then can we find which objects can be affected by the transformation from the database?

Increases in bank interest will cause decreases in housing prices. Increased restaurant prices will increase a less expensive restaurant's profits. It can be seen that the conductive transformation will cause a conductive effect on the information elements with different characteristics and different objects.

Therefore, to understand the conductive effect of transformation by mining from databases the effects of the transformation on the information elements with different characteristics and different objects will provide a basis for future decision making.

2) Knowledge on Conductive Degrees

The functions of extension transformations on other objects and characteristics are represented by the functions on the information elements in databases, and the function degree of the transformation on information elements can be found from the existing data and described by the conductive degree and conductive degree interval. This is the knowledge to measure the conductive effect from quantitative angles.

3) Knowledge on the Changing Range of Corresponding Measure of Conductive Characteristics

After a conductive characteristic is found, its corresponding measure range can be found as well. The function size of a conductive transformation can also be learned by comparing the change of measure range about the characteristic before and after the transformation.

4) Knowledge on Whether the Transmitted Information Element Generates Quantitative Change or Qualitative Change

After obtaining the above conductive knowledge, we can learn whether the information element after conductive transformations (referred to as transmitted information element) generates quantitative change or qualitative change according to the obtaining methods of extension classification knowledge, and further conduct extension classification of the transmitted information elements.

(2) Conductive Knowledge Mining Method

To obtain such knowledge about conductive transformations from databases, the following three types of data must be available: 1) data on multiple characteristic measures of a certain object, corresponding to information element set, i.e. information element set with the same object; 2) data on the same characteristic measure of multiple objects, corresponding to information element set, i.e. information element set with the same characteristic; 3) data on multiple characteristic measures of multiple objects, corresponding to information element set, i.e. information element set with different objects and different characteristics.

1) Conductive Knowledge Mining from the Database of Multiple Characteristics' Measures of Certain Objects

It can be known from the divergence property of "one object and multiple characteristics" that any object may have multiple characteristics, while there may be different correlation property between the different characteristics of such objects, and when active transformation are implemented on the measure of certain characteristics, the measures of its correlated characteristics will undergo conductive transformations. We hope to obtain the following knowledge from the data in databases: which characteristics will undergo conductive transformations, how about the conductive degree, how much does the measure change after conductive transformations, and is it quantitative or qualitative change, etc.

To mine conductive knowledge from the database of multiple characteristics' measures of certain object is to mine the conductive knowledge of the transformation about the information element with the same object, i.e. to obtain the following knowledge from the database:

① Conductive characteristic set about active transformation φ ;

② Changing range of the measure corresponding to the conductive characteristic;

③ Conductive degree and conductive degree interval of the transformation about the conductive characteristic;

④ Knowledge of quantitative or qualitative change of the conductive characteristic.

2) Conductive Knowledge Mining from the Database of the Same Characteristic's Measures of Multiple Objects

It can be known from the divergence property of "one characteristic and multiple object" that any characteristic may correspond to multiple objects, while there may be a correlation between these objects about certain characteristics, and when active transformation is implemented on the characteristic measure of a certain object, the measures of its correlated objects will undergo conductive transformations. We hope to obtain the following knowledge from the data in databases: which objects will undergo conductive transformations, how about the conductive degree, how much does the object measure change after conductive transformations, and is it quantitative or qualitative change, etc.

To mine conductive knowledge from the database of the same characteristic measures of multiple objects is to mine the conductive knowledge of the transformation about the information element with the same characteristic, i.e. to obtain the following knowledge from the database:

① Conductive object set about active transformation φ ;

② Changing range of the measure corresponding to the conductive object about characteristic c ;

③ Conductive degree and conductive degree interval of the transformation about the conductive object;

④ Knowledge of quantitative or qualitative change of the conductive object.

3) Conductive Knowledge Mining from the Database of Multiple Objects and Multiple Characteristic Measures

The above two cases are simple or particular cases. In general, there are usually data on multiple objects and characteristics in the databases, and the active transformations of any characteristic measure of a certain object may cause conductive transformations of the object's other characteristic measures or certain characteristic measure of other objects. We hope to mine the following knowledge from the databases: which objects and characteristics will undergo conductive transformation, how about the conductive degree, how much do the object and characteristic measure change after conductive transformations, and is it quantitative or qualitative change, etc.

This case is an integration of the above two cases, and the obtained conductive knowledge includes: conductive characteristic set, changing range of conductive characteristic measure, conductive object set, transformation range of the measure of conductive object set and conductive object about certain characteristic, conductive degree, and conductive degree interval, etc.

3. Database based extension clustering knowledge mining method

The extension clustering will change with the implementation of transformations. The objects of extension clustering in the universe of discourse are basic-elements, and the "location" of basic-element in the universe of discourse is determined by the qualified degree of each basic-element – the dependent function value of the basic-element, to cluster the basic-elements in the universe of discourse.

(1) General Steps of Extension Clustering Methods

Extension clustering is the clustering based on extension transformations, by which we can not only investigate and study the clustering situation before and after the object's transformations, but also obtain the knowledge on the influence of transformations on clustering according to the difference between the clusters before and after the transformations.

The general steps of the extension clustering method are as follows:

1) Suppose the set of the objects to be clustered is universe of discourse *U*, denoted as $U=\{O_1,O_2,\cdots,O_n\}$, and express the objects by information elements according to the conditions of the practical problem, to form the universe of discourse of information elements, denoted by

$$U_I=\{I_i \;\left|\; I_i=\begin{bmatrix} O_i, & c_{i1}, & v_{i1} \\ & c_{i2}, & v_{i2} \\ & \vdots & \vdots \\ & c_{iq}, & v_{iq} \end{bmatrix}\right., i=1,2,\cdots,n\}$$

(2) Select the evaluation characteristic(s) according to the clustering requirements by the practical problem, and conduct clustering

1) In case of single evaluation characteristic *c*, establish the dependent function $k(x_i)=k(c(I_i))$ of the conformed degree of information elements about *c*, and respectively calculate the dependent function values of each information element as $k(x_i), i=1,2,\cdots,n$.

For any one extension transformation $T=(T_U, T_K, T_I)$, establish extension set in U_I:

$$\tilde{E}(T)=\{(I,y,y')|I\in U_I, y=K(I)\in\Re;\ T_I I\in U_I, y'=T_K K(T_I I)\in\Re\}$$

wherein $y=K(I)=k(x)$ is dependent function, indicating the conformed degree of object *I* in universe of discourse U_I about characteristic *c*.

① If an extension transformation is not implemented, all information elements can be clustered according to the size of dependent function values, into 3 classes as most;

② If an extension transformation of information element is implemented, all information elements can be clustered according to the size of dependent function values of the information elements after the transformation, into 5 classes at most;

③ If an extension transformation of dependent function is implemented, all information elements can be clustered according to the size of dependent function values of the information elements after the transformation, into 5 classes at most;

④ If an extension transformation of universe of discourse is implemented, establish new dependent functions for the information elements in the new universe of discourse (or the original dependent functions can be used according to the specific situation), calculate the size of dependent function values, and cluster the information elements in the new universe of discourse.

2) In case of multiple evaluation characteristics $C=\{c_1,c_2,\cdots,c_m\}$, first establish the dependent function values $k(x_{ji})=k(c_j(I_i)), j=1,2,\cdots,m; i=1,2,\cdots,n$ of the conformed degree of basic-elements about each evaluation characteristic c_i, establish the comprehensive dependent function according to the requirement of the practical problem and calculate the comprehensive dependent degree $K(I_i), i=1,2,\cdots,n$.

For any one extension transformation $T=(T_U, T_K, T_I)$, establish extension set in U_I:

$$\tilde{E}(T)=\{(I,y,y')|I\in U_I, y=K(I)\in\Re;\ T_I I\in U_I, y'=T_K K(T_I I)\in\Re\}$$

wherein $y=K(I)$ is comprehensive dependent function, indicating the degree to which the object I in universe of discourse U_I has a certain characteristic.

① If an extension transformation is not implemented, all information elements can be clustered according to the size of comprehensive dependent degree, into 3 classes as most;

② If an extension transformation of an information element is implemented, all information elements can be clustered according to the size of comprehensive dependent degree of the information elements after the transformation, into 5 classes at most;

③ If an extension transformation of dependent function is implemented, all information elements can be clustered according to the size of comprehensive dependent degree of the information elements after the transformation;

④ If an extension transformation of universe of discourse is implemented, establish new dependent functions for the information elements in the new universe of discourse (or the original dependent functions can be used according to the specific situation), and cluster the information elements in the new universe of discourse according to the size of comprehensive dependent degree.

It's obvious that different transformations correspond to different clustering. Since the nature and the human social and economic environment is ever-changing, the characteristic, standard and range of clustering are ever-changing as well. The extension clustering methods just appear to adapt to the clustering under such transformations.

(2) Extension Clustering Knowledge Mining Method

It can be seen from the extension clustering methods that extension clustering is a kind of clustering based on extension transformations, and similar to extension classification knowledge, is a kind of clustering with extension set as set theory basis. Different transformations will correspond to different clustering results. Through extension clustering, we can obtain the following knowledge:

What classes of information elements can be clustered into one class after transformations, and comparing to the cluster before transformations, how many information elements undergo qualitative change and how many information elements undergo quantitative change after the transformations. Besides, the support and confidence of such knowledge can be given, with their definitions and calculation methods similar to that of extension classification knowledge.

Extension clustering can be widely applied in customer analysis, risk analysis, medical treatment, marketing, and other fields.

The extension clustering knowledge mining method is similar to the extension classification knowledge mining method, so it is omitted.

4. Knowledge base based extension knowledge mining method

In the above we mainly introduced the database based extension knowledge mining methods, including the mining of extension classification knowledge, conductive knowledge and extension clustering knowledge, which tell us how to mine the changing knowledge from the changing data. However, in many industries, when facing contradictory problems, people have to consider using the existing knowledge base, select transformations to treat the problem, and learn about what effects will be produced after certain transformations. Thus, we have to use the knowledge base based extension data mining technology to solve problems, in other words, we have to mine the new knowledge based on transformations from the existing knowledge, including the extension knowledge based on the extended knowledge and its mining methods, the extension knowledge based on decision tree knowledge and its mining methods, as well as the extension knowledge in other knowledge bases and its mining methods.

(1) Extension Knowledge Based on Extensible Knowledge and Its Mining Method

The extensible knowledge is the knowledge based on the extensible analysis principles in Extenics. To solve contradictory problems, we must first conduct extensible analysis of the problem's goal and condition, by which to obtain more extended knowledge. Entry of such knowledge into knowledge base, on the one hand, can serve problem solving, on the other hand, after extension transformations of such knowledge, we can obtain the extension knowledge based on such knowledge that can also serve problem solving.

Extensible knowledge includes divergent knowledge, correlative knowledge, implicative knowledge and opening-up knowledge. As to the extensible knowledge obtained according to the extension rule, when a certain extension transformation is implemented on the antecedent of the rule, conductive transformations will occur on its consequent, and the rule knowledge obtained after the transformations is referred to as the extension knowledge on the rule knowledge before transformations, which includes the extension knowledge of divergent knowledge, the extension knowledge based on correlative knowledge, the extension knowledge based on implicative knowledge, and the extension knowledge based on the opening-up knowledge.

It can be seen from the extensible knowledge and extension knowledge introduced above that, to obtain extension knowledge from the extensible knowledge, we must first store such extensible knowledge in a knowledge base. On this basis, the general steps to obtain such extension knowledge are:

1) Extract one piece of knowledge from the extensible knowledge base, and implement certain active extension transformation of its antecedent;

2) According to the conductive transformation principle, obtain the conductive transformation and its transformation condition ℓ occurred on the knowledge's consequent;

3) Express the relation between such active transformation and conductive transformation by production rule, to obtain a piece of extension knowledge.

(2) Extension Knowledge Based on Decision Tree Knowledge and Its Mining Method

Decision tree is a kind of structure. Through applying simple decision rules, we can use such structure to segment large records into interconnected small record sets. Through each continuous segmentation, the centralized members in the result set become more and more similar. The rule obtained from the decision tree is referred to as the decision tree knowledge that is the basis for us to further obtain the extension knowledge.

The general steps to mine the extension knowledge based on decision tree classification knowledge are:

1) First construct a decision tree according to the basic thinking of recursion, extract the rule model from it and evaluate the obtained data model, to obtain the rule knowledge.

2) On the basis of the above obtained rule knowledge base, analyze the contradictory problem, implement feasible extension transformations, and find the feasible strategy by superiority evaluation technology, to obtain the extension knowledge.

(3) Extension Knowledge Based on Other Knowledge Bases and Its Mining Method

The mining method of extension knowledge based on other knowledge bases mainly studies the mining of the extension knowledge chain based on the subject, the extension knowledge to solve contradictory problems, and the extension knowledge based on property reduction transformation and data mining transformation, etc. which are omitted.

5.3.3 Development Prospect of Extension Data Mining

With the rapid development of information technology, the management information system, internet, data mining and knowledge management are continuously accumulating more and more data, information and knowledge. In this situation, the enterprise needs more deep and practical knowledge to support its decision. For example, in the current market competition that has become more intensive day by day, customers become the important resource, so the knowledge on transformations will help transform the customers who register for the first time or are going to be lost to loyal customers, to reduce the cost for customer maintenance and development of new customers; in credit risk analysis, it’s required not only to identify high risk customers, but also to adopt measures to urge the customers with the motivation of fraud to stop their action, in which the extension classification method and its relevant knowledge are extremely useful; in the development of new products, the knowledge on implication analysis can help discover product trend and identify the potential customer demand as soon as possible; in business flow optimization, extension data mining can help find the efficiency affecting bottlenecks and make transformation measures; in medical industry, the knowledge on transformations can help doctors discover the basic change of symptom as soon as possible, and identify the most effective program to improve the treatment effect; in marketing, the knowledge on transformations has guiding significance in market development. In summary, extension data mining can exert functions in transforming the object classification, discovering the problem’s main reasons, and identifying the potential transformation knowledge, etc. Hence, extension data mining enjoys a broad application prospect.

The extension engineering produced by integrating the extension theory and extension method with information, management and other fields has achieved preliminary results. At present, in the field of extension data mining, some experts have studied partial problems existing in the data mining above-mentioned by Extenics principle and methods, in terms of the theory, method, algorithm, application program, and technological improvement, etc. of extension data mining, achieved certain results. With the deepening and strengthening of the studies, it’s hopeful to achieve the study results with more application values.

With the advance of economic globalization, the stepping of knowledge economy is also significantly accelerating, the uncertain environment causes shorter updating cycles of information and knowledge, and innovation and solution to contradictory problems increasingly becomes the important works in various industries. Therefore, how to mine the transformation knowledge becomes the vital task for the study on data mining.

The focal points of the current study on extension data mining are limited in the relational database or rules knowledge base. Actually, in the studies on text data, image or video data, and Web data, it should also be considered that the influence of transformations on data is a field that should be involved in the extension data mining. The extension knowledge mining from data warehouse is also beginning, and is to be further studied in-depth.

5.4 Extension Marketing Method

The arrival of knowledge economy age raises lots of new subjects for marketing researches. Traditional marketing theories and methods are bound to be improved and updated with the extension of human thinking and expansion of view. The rapid development of scientific technology, popularity of network and application of e-commerce make the life cycle of products shorter and shorter. Many products start to develop toward individuation, fashion, knowledgeable, intellectualization and digitization. The stableness of market becomes weaker and weaker with shorter and shorter marketing channels, which raises more new requirements to enterprises. It requires that the enterprises have a new understanding of the concept of “customers”, know the rules for product expansion and analyze products, market, and resource, enterprise construction with new ideas.

With increasingly fierce market competition, enterprises have to face lots of competitors to survive and develop. They fight for competitive advantage, seizing market share and realizing differentiation, which lead to the fiercest competition among enterprises; they are greatly damaged to seize increasingly reduced profits. The way to get rid of this passive situation is “innovation”.

In 2000, the monograph *Extension Marketing* [25] proposed extension marketing theory and methods starting from “innovation”. It includes contents in three aspects: the first is product innovation, raising product innovative theory and methods through extensible analysis and extension transformation; the second is market innovation, raising the theory and methods of expanding market with the tool of extension set; the third is business innovation, proposing to reform the theory and methods of enterprise based on object conjugation. This kind of extension marketing theory and methods is effective theory and methods for enterprises to get rid of passive situation adjustable to the fierce environment of market competition.

In 2005, the *Blue Ocean Strategy* [26] published by Harvard Business School Press has the same ideas with monograph [25]. It raised the method of value innovation and creating Blue Ocean. It is partial application of extension marketing theory and methods from the angle of practice. The core is creating new products or services.

Monograph [25] introduced the research background of extension marketing, basic ideas and substantive achievements of extension marking theory and methods, based on which this section will mainly introduce extension marketing methods, including product innovative method, market expanded method, resource extension method and business innovative method.

5.4.1 Way to Product Innovation

The new features of the knowledge economy age raises new requirements on product innovation. If the enterprise can grasp product extension rules and methods, the market can be grasped as well. Product extension theory starts with the possibility (i.e. extensibility) and sequence of product extension to study product extension rules and give formalized representation so as to research new product development software and forecast the appearance of new products.

1. Product extension rules and methods

The study of product extension rules and methods with extension theory mainly has the following features:

(1) Start from the Research of Consumer Demand to Study Product Extension Rules and Methods

The research of product extension rules must start from the study of consumer demand, for consumers purchase products to meet their own needs rather than the products themselves. If the enterprise can find unsatisfied, promotable and sustainable needs, it always can have foresight, do what others cannot do, seize business opportunities and markets. There are many researches on the levels of consumer demand now, but the way to analyze and find consumer demand is more important. We have given formalized representation of the demand with affair-elements in Extenics, studied demand extensibility and offered formalized analytical methods of demand. Consumers' demand and product functions are corresponding, thus formalized thinking starting from the demand for creating new products can be offered to facilitate product developers to come up with new products.

(2) Study Product Extension Methods through Product Extensible Analysis, and Research the Way to Create Complete Products Based on Conjugate Analysis of a Product

From the point of view in Extenics, any product can be described with multi-dimension or dynamic matter-elements. Products have extensibility, thus formalized methods of innovative products can be formed through product extensible analysis with extension transformation after fully considering the variation relations of products and technology, society, economy, environmental protection and time etc.

Besides, all products have imaginary and real parts, soft and hard parts, latent and apparent parts, negative and positive parts. Only these eight parts are properly matched can the products become integral ones.

(3) Create Corresponding New Products through Making Conjugate Classifications of Products

Technological progress leads to more and more product forms, shorter and shorter product life cycles and qualitatively changed product category. Therefore, it is necessary to classify products from new angles—the angle of meeting people's needs so as to make different product innovative programs for products of distinct types. Their marketing rules and methods should be respectively studied as well. While classifying from the angle of whether the products meet people's needs as a material substance or immaterial form, we divide products into real and imaginary products; while classifying from the angle of whether the products meets people's needs of forming the hard part of certain system or the needs of establishing certain relations, we divide products into hard and soft products; while classifying from the angle of product pros and cons to people's certain features, they can be divided into positive and negative products; while classifying from the angle of meeting people's certain needs obviously or potentially, they can be divided into apparent and latent products.

(4) Give the Rhombic Thinking Mode of Product Conception to Make People's Product Innovative Activities have Rules to Obey

The process of product extension is a rhombic thinking process. No matter conceive new products from needs, existing products or demerits and needs of existing products, they all rely on this kind of thinking mode. Make divergence first based on extensibility, then make convergence through superiority evaluation, finally get the conception program of usable products. The advantage of this kind of rhombic thinking mode lies in that it offers a formalized operating mode to facilitate product innovation personnel to grasp and use.

Set R as a product matter-element, $R_1, R_2, \ldots, R_n$ are the matter-elements extended by R according to extensibility, $R_1', R_2', \ldots, R_m'$ refers to the matter-elements after evaluation and convergence ($m<n$), thus the rhombic thinking mode is as shown in Figure 5.13:

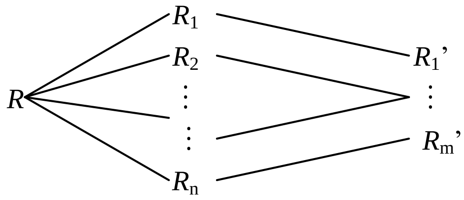


Figure 5.13 Rhombic Thinking Mode of Product Conception

2. Product innovation ideas

In reference [25], we raised three creativities of innovative products. Concrete steps of the three creativities will be introduced in the extension design method of 5.6. Only product innovation ideas are introduced here.

To expand new products, there should be corresponding methods and technology. Extensible analysis method and extension transformation method offer feasible approaches to it.

(1) Product Innovation Starting from the Needs—First Creative Method

The first creative method to conceive new products with extension methods refers to the method of conceiving new products from the consumers' demand on product function. The so-called new products are the outcomes of new technology, invention and discovery, which have no precedent. The birth of such products will change people's life style and cause "consumption revolution".

In fact, products are objects with the function of meeting people's certain needs. Needs are the mother of creation. Starting with needs can create product (or services), and then create market, enterprise and even industry. For instance, Ms. Pang, a laid-off female worker from Shanghai, has a good understanding of people's tense and busy work in large cities. She knows many people need to "washed and sliced vegetables" to save the time for washing and slicing vegetables after work, thus she specially "produces" "washed and sliced vegetables" with a batch of laid-off female workers, which is very popular. With expanded business, "Ms. Pang Clean Vegetable Company" emerged at the right moment.

It can thus be seen that conceiving new products from meeting consumers' unsatisfied "needs" can create new products. This is a good way to aid competition and create Blue Ocean.

First creative method doesn't aim to conceive new products initially but resolve the contradiction that products in current market cannot meet the consumers' certain needs. It is mainly used for developing products of following types:

1) Develop alternative products

Alternative means for some product or services, their functions and forms are entirely different but serve the same upper function. For instance, we can see a movie, play mahjong or go to internet bar etc. for pastime. They have different functions and forms but serve the same upper function "pastime". These corresponding products with lower function of the same upper function are alternative products. These "alternative products" can be found through establishing implication system.

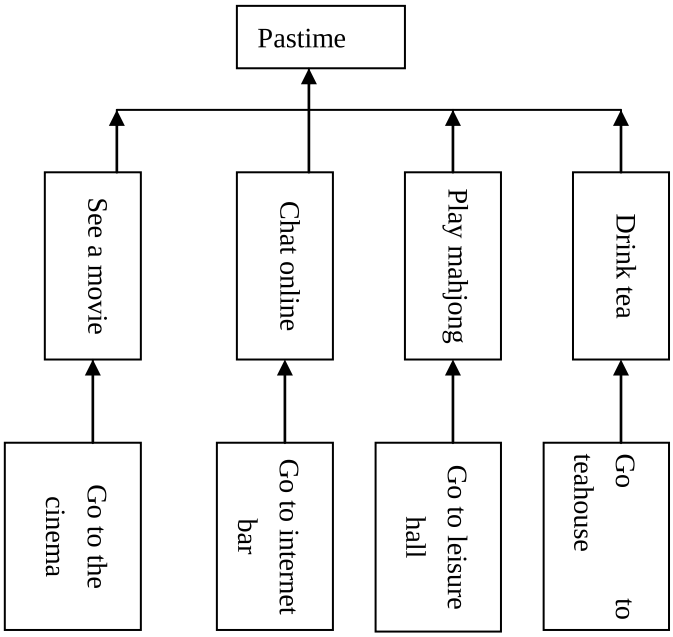


Figure 5.14 The Implication System about "Pastime"

For pastime, movie, internet bar, leisure and entertainment, and teahouse are alternative industries. Their products are alternative products.

We can find the products with different functions of the same upper function through establishing functional systems. For instance, one American company transformed "offering decoration" as "offering decoration skills and materials" through analyzing people's needs for "decoration" and achieved great success.

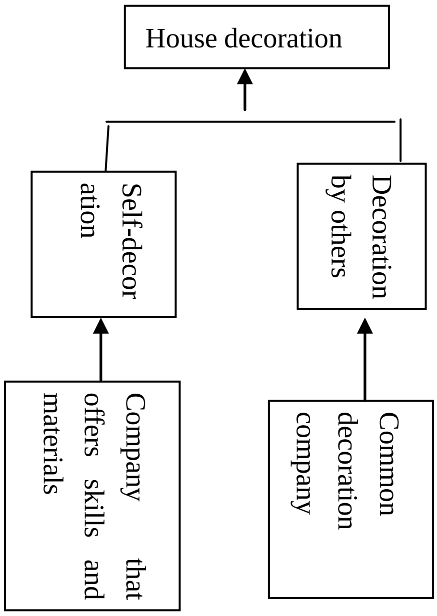


Figure 5.15 The Implication System about "House Decoration"

The customers purchase materials and decoration skills from Home Depot China to get the fun of amateur self-decoration and money saving effects. Its products are alternative products compared with those of common decoration companies.

2) Develop integrated products

Besides the products that can meet two different needs, developing products that can meet these two needs simultaneously are integrated products. For instance, people use cell phones to give and answer the call and computers can help people transmit words and information via networks. The combination of these two needs forms the concept of "WAP phone". The combination of sound reception and recording generated the idea of manufacturing radio cassette.

3) Develop complementary products

Book purchasers have the needs of buying and reading books and drinking tea. The combination of these needs is the bookstore with attached teahouse. The adults shopping around hope that there is a nursery in the shopping mall and young couples seeing a movie also hope there is a nursery at the cinema. Then babysitting service at cinemas and stores correspondingly appear.

4) Develop terminal products

Some products can meet user demand through intermediate links. If the needs can be directly satisfied through analyzing users' final demands, new products can be created as well. For instance, diabetics need to be injected with insulin. In the past, insulin was put in phial and the doctor made a prescription to sell it to the patients. Lots of patients need to be injected many times every day, thus it was very inconvenient to use this medicine. Therefore, someone created the pen to inject insulin. This kind of pen has an automatic adjusting button, which eliminates most problems for the patients. This creation changed the enterprise from insulin producer to diabetes mellitus curer.

(2) Create New Products from Existing Products through Extension Transformations—Second Creative Method

To seize market share and get the "cake" of larger share, many enterprises take extraordinary moves based on product features, which makes the cost invested in these features higher and higher. To create new products, the extensibility of products can be used to find other features and create products with more distinguishing features. These product features can also be used to create new products through four basic transformations or operations.

(3) Create New Products from a Product's Demerits—Third Creative Method

For a product, investigate the opinions of customers that are unwilling to purchase. Find the unsatisfied features of noncustomers through analysis and then improve these "demerits" so as to create new products. For instance, for the wine, some noncustomers think it is difficult to select due to high price and complex taste. Aiming at these opinions of noncustomers, "yellow tail wine" produces the wine with simple taste, low price and only two styles. It just creates new products based on noncustomers' needs.

On the other hand, original customers' demand on new products should be kept as well. New products can not only meet the noncustomers of old products but also can keep the key demerits of old products, which make the customers of old products like the new products. "Yellow tail wine" keeps the original merits of wine and makes original wine customers also like this simple yellow tail wine.

That is to say, the customers of new products include two types: a) Part of noncustomers of original products; b) Part of customers of original products. The marketization of this product is much larger than the market of old products.

5.4.2 Market Expanded Method—Find Extension Market

A market is a very complex and multilayer concept. In different social and economic formations, it has distinct connotations. Many factors can lead to market change and there are lots of forms of change. The study of the causes and rules of market change will offer a reliable basis for expanding markets. In the market economy, if the enterprise grasps the rules of market changes and the methods of expanding markets, it can formulate correct marketing strategies so as to make the enterprise succeed. In marketing, there has been the study of market evolution before. It has intensive research on the consumers' purchase intension and decision but without complete research on market's formalization analysis and the mechanism of expanding markets.

The reason of enterprise, customers as well as social and economic environment can lead to the change of market. The degree of change will alter with the products' different stages in the life cycle. Based on the concept of marketing markets, the market of certain products refers to the set of customers that are able and willing to buy it. Therefore, the market of certain products is decided by two features of consumers—purchase intention and capacity. No matter what reason causes the change of market, it is the transformation of customers' purchase intension and capacity ultimately. To explore the mechanism of expanding market and describe market change process with formalized methods, we adopt the idea of extension set to make formalized analysis of this market set and propose the concept of extension market. We also analyze the type and realization methods of extension market so as to provide the idea and formalized methods of extension market for enterprises.

1. Concept of extension market

The so-called extension market is comparatively speaking to a certain transformation. If people that don't belong to the market can be changed to those belonging to the market under transformation *T*, the set composed of these people is called the extension market of original market on transformation *T*.

For instance, for the market of passenger transport from Guangzhou to Shenzhen, all people in Guangzhou that are willing and capable to go to Shenzhen belong to this market. All people in Guangzhou (including floating population) are the universe of discourse. Certain transformation e.g. lower ticket price, build new scenic spots in Shenzhen, help handle boarder permit, can make people that are unwilling or incapable, impossible to go to Shenzhen enter the market. The set composed of these people is the extension market of the original market, and the corresponding transformation is the strategy of expanding market.

Now let's give the concept of extension market with the idea of extension set:

Set certain product (or product mix) is sold in given region, record people in this region as universe of discourse *U* and then product dull sale is the contradictory problem of enterprise. Analyzing from the perspective of marketing, the core problem is the contradiction produced by the products supplied by enterprise, and consumers' purchase capacity and intention.

For consumer O, $O\in U$, take evaluation characteristic c_{01}="purchase intention" and c_{02}= "purchase capacity". If one of the two evaluation characteristics doesn't conform to the requirement, the problem will be incompatible problem.

For evaluation characteristic c_{01}= "purchase intention" and c_{02}= "purchase capacity", the classic domain $X_{01,}X_{02}$ and joint domain $X_{1,}X_2$ of the quantity value can be obtained based on marketing knowledge through market investigation or extension data mining. Obviously, $X_{01}\subset X_{1,}$ $X_{02}\subset X_{2.}$ Thus for certain consumer $O_{0,}$ the core problem is

$$P_0 = g_0 * l_0 = \begin{bmatrix} O_0, c_{0s1}, X_{01} \\ \quad c_{0s2}, X_{02} \end{bmatrix} * \begin{bmatrix} O_0, c_{0t1}, x_{01} \\ \quad c_{0t2}, x_{02} \end{bmatrix}$$

Wherein, g_0 refers to basic-element of purchase capacity and intention required by purchasing certain product of consumer O_0. l_0 refers to the basic-element of existing purchase capacity or intention of consumer O_0.

According to reference [27], respectively establish dependent functions $k_1(x_1)$ and $k_2(x_2)$ about evaluation characteristics $c_{01}$and c_{02}.

For any $l=\begin{bmatrix} O, c_{01}, x_1 \\ c_{02}, x_2 \end{bmatrix} \in W$ and given transformation $T=(T_W,\ T_K,\ T_l)$, establish extension set

$$\tilde{M}(T)=\left\{ (l,y,y') \;\middle|\; l\in W, y=K(l)=k_1(x_1)\wedge k_2(x_2); T_l l\in T_W W, y'=T_K K(T_l l)\right\}$$

call

$$\underset{\bullet}{M}_{+}(T)=\left\{ l \;\middle|\; l\in W, y=K(l)\le 0; T_l l\in T_W W, y'=T_K K(T_l l)>0\right\}$$

the positive extension field of the problem, i.e. the extension market [26] about transformation T of the original market. Call

$$M_{+}(T)=\left\{ l \;\middle|\; l\in W, y=K(l)>0; T_l l\in T_W W, y'=T_K K(T_l l)>0\right\}$$

the positive steady field of the problem. It is a part of the original market, a part of the market that is kept after the transformation. Obviously $\underset{\bullet}{M}_{+}(T)\cup M_{+}(T)$ is the new market after the transformation T.

Especially when $M_{+}(T)=\varnothing$, it means the new market after the transformation is a brand new market.

Based on concrete problems, form basic-element l and establish dependent function $y=K(l)=k_1(x_1)\wedge k_2(x_2)$ for any consumer O according to evaluation characteristics. If

$$y_0=K(l_0)=k_1(x_{01})\wedge k_2(x_{02})<0\,,$$

it means the products offered by the enterprise cannot meet the consumers' purchase capacity or intention, i.e. the original problem is an incompatible problem. Through implementing transformation $T=(T_W,\ T_K,\ T_l)$, if we make

$$T_K K(T_{l_0} l_0)=K'(T_{l_0} l_0)=K'(l')>0$$

then the incompatible problem is considered as a compatible problem. Wherein, transformation T is the resolving transformation of the original problem.

2. Types of extension markets

Different transformations correspond to distinct extension markets. According to the concept of extension markets, there are following types of extension markets:

(1) Extension Market about Transformation T_l

In $\underset{\cdot}{M}_+(T)$, if $T_W = e$, $T_K = e$, then the following set is called the extension market of original market about transformation T_l.

$$\underset{\cdot}{M}_+(T)=\{\ l\ \mid l\in W, y=K(l)\le 0; T_l l\in W, y'=K(T_l l)>0\}$$

It is the extension market transformed about the customers' purchase capacity or intention, and its meanings are as follows:

① Through certain transformations, people who are unwilling to purchase certain products can be changed to willing to purchase. The set composed of these people is the extension market of the original market. For instance, many people are unwilling to buy ice cream in winter. An ice cream seller can convince customers to buy the ice cream after offering salty fried peas that will propel people to buy ice cream for dessert.. They form the extension market of the ice cream market.

Through certain transformations, the originally weak purchase intention is strengthened. For instance, sale with gift, improving service quality and beautifying sale environment can strengthen the consumers' purchase intention and extend the market.

② Through certain transformations, people without the capacity of purchasing certain products become capable to purchase. They form the extension market of the original market. For instance, mortgage, installment payments, overdraft and individual consumption loans are all methods of transforming purchase capacity, or called "premature consumption". It makes many people with low purchase capacity have the demands on products and become the extension market of this product.

(2) Extension Market about Transformation T_K

In $\underset{\cdot}{M}_+(T)$, if $T_W = e$, $T_l = e$, then the following set is called the extension market of original market about transformation T_K.

$$\underset{\cdot}{M}_+(T)=\{\ l\ \mid l\in W, y=K(l)\le 0, y'=T_K K(l)>0\}$$

It is the extension market about dependent criterion transformation. Its meanings are: people who are unwilling or incapable to purchase certain products are changed to have purchase intentions and capacity through transforming the dependent criterion of problems. Thus these people compose the extension market of original markets. For instance, the measure of changing the initial payment for buying a car from 50% of the car price to 20% expands the market, which is the extension market of original market about the change of initial payment.

(3) Extension Market about Transformation T_W

In $\underset{\cdot}{M}_+(T)$, the following set is called the extension market of original market about transformation T_W.

$$\underset{\cdot}{M}_+(T)=\{\ l\ \mid l\in W, y=K(l)\le 0;\ \ l\in T_W W-W,\ \ y'=K'(l)>0\}$$

Wherein, $l\in T_W W-W$ refers to the universe of discourse after transformations, but it doesn't belong to the entire basic-elements of the original universe of discourse.

It is the way to find the extension market through the transformation of the universe of discourse, i.e. the commonest new market extension method in marketing. For instance, change the regulation of buying a house via an identity card of the city to the regulation of buying via an identity card, which makes the market expand from the city to nationwide. People who are capable and willing to buy a house in the city become the extension market of the original market about the transformation of this regulation.

(4) Extension Market about Conductive Transformations

If an incompatible problem cannot be resolved through transformation $T=(T_W, T_K, T_l)$, we can consider finding extension markets through the conductive transformations of certain transformations. For instance, through the transformation of products, transformation of product users and transformation of time etc., people's purchase capacity or intention can be changed so as to form the extension market about conductive transformations. For instance, the attached primary school of one famous school is built on certain premises, which causes the clients buying this premises greatly increased. All those who are willing to buy a house because their children want to study in this primary school are the extension market of original market about the transformation of adding famous school.

(5) Extension Market about Transformation Combinations

If an incompatible problem cannot be resolved through transformation $T=(T_W, T_K, T_l)$, we can consider using the arithmetic expressions of these transformations, including the product transformation, AND transformation, OR transformation and inverse transformation of several transformations.

The type of transformation T decides the property of extension market. According to different transformations, the extension market can be classified into distinct types with various realization ways. The study of the extension market makes the process of extension marketing have rules to obey. The enterprise can find various ways to extend market through transformations according to practical situation. See detailed content in reference [28].

In fact, various ways to extend market represented in reference [26] are extension markets under different transformations. The application of different extension transformations can obtain distinct extension market strategies. The market represented in this book is a part of the extension market. A basic idea of this book is to avoid competition and not divide market share with competitors but rebuild new market (i.e. create blue ocean). Such as the typical case in this book "Market extension method of Sun Circus". In fact, it adopts the method of combining the conductive transformation and universe of discourse transformation of product transformations. It avoids the "kinds market" with fierce competition but expand brand new "adults, business people" market. Take the "method of rebuilding market border" in this book for another example. In fact, it is the method transformed by dependent criterion (or the function of compatible degree). Interested readers can conduct case control study.

The example below is just to expand market through product transformations (i.e. product innovation). The obtained extension market is the extension market about the conductive transformation of product transformations.

[Example 5.2] A wine company constantly fails in the fierce market competition and cannot achieve the preset profits goal. Thus it analyzes the wine industry and tries to find the solution.

The goal of the enterprise is:

$$G_0 = (\text{Enterprise } A, \text{annual profit}, 10,000,000\text{Yuan})$$

and the condition is

$$L_0 = \begin{bmatrix} \text{Wine } B, & \text{annual sales volume}, & 1000,000\text{tons} \\ & \text{cost}, & 40,000\text{Yuan/ton} \\ & \text{unit price}, & 80,000\text{Yuan/ton} \end{bmatrix}$$

They compose problem $P_0 = G_0 * L_0$.

According to marketing knowledge:

$$(\text{Enterprise } A, \text{annual profit}, a) \sim (\text{wine } B, \text{ annual sale volume}, a_1) \sim \begin{cases} (\text{wine } B, \text{ cost}, a_2) \\ (\text{wine } B, \text{ unit price}, a_3) \end{cases}$$

Establish the function of compatible degree of the problem as $K_L(G) = k(a_1, a) = (a_1 \times a_3 - a_1 \times a_2) - a$. Obviously for problem P_0, its compatible degree is $K_{L_0}(G_0) = (100 \times 8 - 4 \times 100) - 1000 = -600 < 0$, i.e. problem P_0 is an incompatible problem.

For any consumer basic-element

$$l = \begin{bmatrix} \text{Consumer } O, \text{purchasec apacity} c_{01}, x_1 \\ \text{purchase intention } c_{02}, x_2 \end{bmatrix} = \begin{bmatrix} O, c_{01}, x_1 \\ c_{02}, x_2 \end{bmatrix},$$

according to the definitions of extension market and new market, for a given transformation $T=(T_W, T_K, T_l)$ and $y = K(l) = k_1(x_1) \wedge k_2(x_2)$, all sets of consumers that can meet

$$\underset{\cdot}{M}_+(T) = \{ l \mid l \in W, y = K(l) \le 0; T_l l \in T_W W, y' = T_K K(T_l l) > 0 \}$$

and

$$M_+(T) = \{ l \mid l \in W, y = K(l) > 0; T_l l \in T_W W, y' = T_K K(T_l l) > 0 \}$$

is the new market of a certain product.

Now consider adopting product transformation to make conductive transformation of consumers' purchase capacity and intention according to the correlation of the product and the consumer so as to expand new market and realize the business goal.

First make correlative analysis of the corresponding class basic-element L of L_0 to find the root cause. Set

$$L = \begin{bmatrix} \text{Wine } B, & \text{annual sale volume}, & a_1 \\ & \text{cost}, & a_2 \\ & \text{unit price}, & a_3 \end{bmatrix} = \begin{bmatrix} L_{a_1} \\ L_{a_2} \\ L_{a_3} \end{bmatrix}$$

then

$$L \sim L_1 = \begin{bmatrix} \text{Wine } B, & \text{ageing quality}, & v_1 \\ & \text{type}, & v_2 \\ & \text{reputaiton of producing area}, & v_3 \\ & \text{promotion investment}, & v_4 \end{bmatrix} = \begin{bmatrix} B, & c_1, & v_1 \\ & c_2, & v_2 \\ & c_3, & v_3 \\ & c_4, & v_4 \end{bmatrix}$$

The fierce competition makes the enterprise focus its cost on the above four features. The consumers often consider these four features to confirm whether to purchase. The company changes its former strategies through investigating noncustomers, i.e. people who don't drink wine but drink beer and other drinks, to find their reasons for not drinking wine. The company has found they are unsatisfied with three other features of wine: edibility, selectivity and special taste, i.e. according to divergent analysis, there is

$$L_1 \longmid L_2 = \begin{bmatrix} \text{Wine} B, & \text{edibility}, & v_5 \\ & \text{slectivity}, & v_6 \\ & \text{special taste}, & v_7 \end{bmatrix} = \begin{bmatrix} B, & c_5, & v_5 \\ & c_6, & v_6 \\ & c_7, & v_7 \end{bmatrix} = \begin{bmatrix} L_{25} \\ L_{26} \\ L_{27} \end{bmatrix}$$

Thus the company decides to expand the market through product innovation. Obviously, the following correlative network exists:

$$L_{a_1} \sim l \sim \begin{Bmatrix} L_{a_2} \\ L_{a_3} \end{Bmatrix} \sim \begin{cases} L_1 \\ L_2 \end{cases}$$

Second, make an expansion transformation for L_2 to make the product expand the quantity value of features like edibility, selectivity, interest and adventure, i.e. make transformation

$$\varphi_2 L_2 = \begin{bmatrix} B', & c_5, & \alpha_5 v_5 \\ & c_6, & \alpha_6 v_6 \\ & c_7, & \alpha_7 v_7 \end{bmatrix} = \begin{bmatrix} B', & c_5, & v_5' \\ & c_6, & v_6' \\ & c_7, & v_7' \end{bmatrix} = L_2', \ (\alpha_5 > 1, \alpha_6 > 1, \alpha_7 > 1)$$

Then make a contraction transformation for L_1 to largely reduce the requirements on v_1, v_2, v_3, v_4, i.e. make transformation

$$\varphi_1 L_1 = \begin{bmatrix} B', & c_1, & \alpha_1 v_1 \\ & c_2, & \alpha_2 v_2 \\ & c_3, & \alpha_3 v_3 \\ & c_4, & \alpha_4 v_4 \end{bmatrix} = \begin{bmatrix} B', & c_1, & v_1' \\ & c_2, & v_2' \\ & c_3, & v_3' \\ & c_4, & v_4' \end{bmatrix} = L_1', (0 < \alpha_i < 1, i = 1, 2, 3, 4)$$

$\alpha_i > 1$ means expansion, $\alpha_i < 1$ means contraction, i.e. transformation $\varphi = \varphi_1 \wedge \varphi_2$ changes wine B to a new wine B'. Set B' as yellow tail wine, i.e. form a new product. Set

$$L' = L_1' \oplus L_2' = \begin{bmatrix} \text{yellow tail wine } B', & c_1, & v_1' \\ & c_2, & v_2' \\ & c_3, & v_3' \\ & c_4, & v_4' \\ & c_5, & v_5' \\ & c_6, & v_6' \\ & c_7, & v_7' \end{bmatrix}$$

Since contraction processing is made for the quantity value of yellow tail wine on features c_1, c_2, c_3, c_4 compared with corresponding quantity value of the original wine, according to the correlation, there is conductive transformation

$$_{\varphi}T_{L_{a_2}} L_{a_2} = L'_{a_2}, \quad _{\varphi}T_{L_{a_3}} L_{a_3} = L'_{a_3},$$

i.e. largely reduce the cost and price. Record $T_1 = {}_{\varphi}T_{L_{a_2}} \wedge {}_{\varphi}T_{L_{a_3}}$, then to the conduction of transformation T_1 changes the purchase intension of many consumers. It makes lots of people drinking beer and other drinks purchase yellow tail wine. Then there is a conductive transformation

$$_1T_l l = l' = \begin{bmatrix} O, & c_{01}, & x_1' \\ & c_{02}, & x_2' \end{bmatrix}.$$

Under this transformation, all consumers that can meet $K(l) = k_1(x_1) \wedge k_2(x_2) \le 0$ and $K(l') = k_1(x_1') \wedge k_2(x_2') > 0$ form the extension market of new product "yellow tail wine", which is recorded as $\dot{M}_+({}_1T_l)$. Wherein, x_1', x_2' are respectively the values of purchase capacity and intention of consumer O for yellow tail wine. k_1 and k_2 are respectively the dependent functions of purchase capacity and intention.

On the other hand, since yellow tail wine still keeps the features of wine, some wine drinkers begin to drink yellow tail wine due to the price fall cased by transformation T_1, i.e. all consumers that can meet

$$K(l) = k_1(x_1) \wedge k_2(x_2) > 0, \text{ and } K(l') = k_1(x_1') \wedge k_2(x_2') > 0$$

is the stable market of new product "yellow tail wine, which is recorded as $M_+({}_1T_l)$.

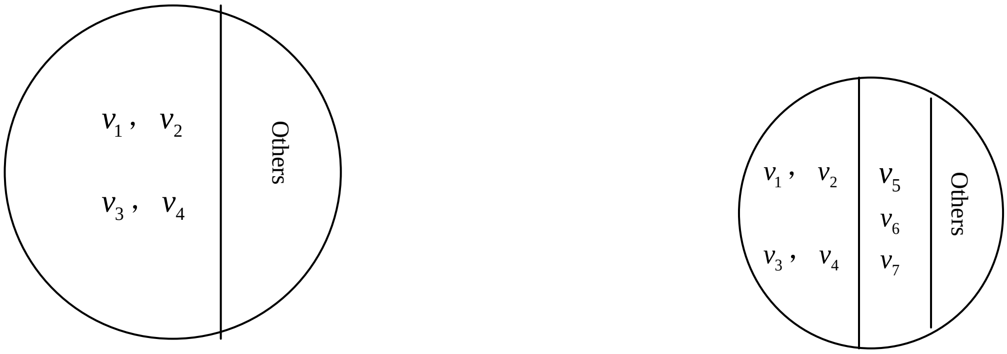
Then new market expanded through product innovation can be obtained as $\dot{M}_+({}_1T_l) \cup M_+({}_1T_l)$. Then based on $L_{a_1} \sim l$, transformation $_1T_2$ is bound to make L_{a_1} have conductive transformations, i.e. increase the annual sale volume of new products and then increase annual business profits. Suppose

$$L_0' = \begin{bmatrix} \text{Yelow tail wine} & B', & \text{annual sale volume,} & \text{5,000,000tons} \\ & & \text{cost,} & \text{20,000Yuan/ton} \\ & & \text{unit price,} & \text{40,000Yuan/ton} \end{bmatrix},$$

then the compatible degree of the original problem under new product conditions is

$$K_{L_0'}(G_0) = (600 \times 4 - 2 \times 600) - 1000 = 200 > 0,$$

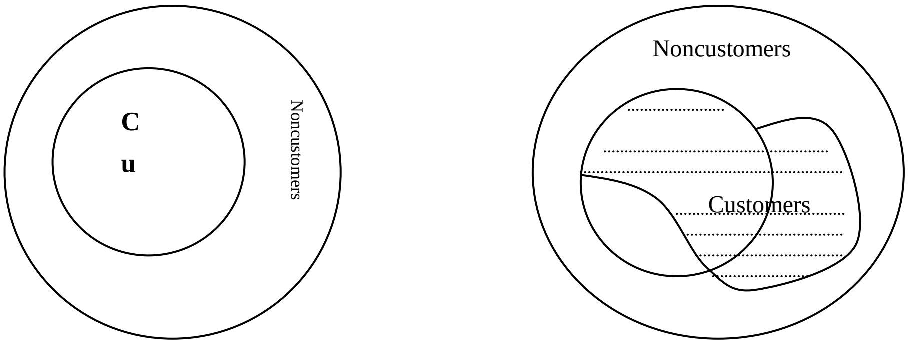
which transforms the original incompatible problem to a compatible problem. Due to launching "yellow tail wine", the company becomes the largest wine company in America as shown in Figure 5.16 and 5.17.



Distribution of Wine Cost

Distribution of Yellow Tail Wine Cost

Figure 5.16 Pie Chart of Cost Consumed by Corresponding Quantity Values of Features of Wine and Yellow Tail Wine



Wine Customers

Yellow Tail Wine Customers

Figure 5.17 Pie Chart of Wine and Yellow Tail Wine Customers

5.4.3 Resource Extension Method—Find Extension Resources

There are various types of resources and different enterprises have distinct resource contradictions. To realize business goals, entrepreneurs must analyze various resources carefully and obtain long-term business profit through developing and utilizing various resources.

Enterprise operations need various resources. Due to the influence of our cognitive ability and "occupation concept", people always pay attention to controllable resources of the enterprise, which are called controllable resources by us. Under this circumstance, many entrepreneurs think the more the employees, wealth and objects in the enterprise, the better and the more severely the enterprise expands. With technological development, the speed for product update is accelerated. There are always large differences from conception, design to each stage of product manufacture, thus controllable resources are more and more difficult to meet the enterprise's demand. Then other social resources need to be adopted to resolve the contradiction of insufficient business resource. All-inclusive enterprises are more and more difficult to adapt to social development, which requires entrepreneurs to expand from utilizing "controllable resources" to using uncontrollable resources outside the enterprise. From now on, the proportion of utilizing uncontrollable resources by enterprises will be larger and larger. The degree of openness of enterprises will also be higher and higher. The key for whether the enterprise can survive and develop in fierce competition doesn't lie in the quantity of the enterprise's controllable resources but the capacity of utilizing uncontrollable resources. The enterprise may not be closed physical enterprise with large scale but a flexible organization with the core of high capacity that can allocate uncontrollable resources through multiplication chain.

For any organization, the problem of resource management and utilization exists. For various types of resources, no matter human resource, financial resource, power resource, material resource and non-material resource etc., there are special researches. But for many organizations, most of them focus on controllable resources because they think only controllable resources can be controlled. It is the traditional resource based view. While analyzing from the perspective of Extenics, resources have extensibility, i.e. resources have divergence, correlation, implication and expandability. Material resource also has conjugacy. The extensibility of resource provides all possible ways for enterprise resource extension. With the knowledge of extension set and dependent function, we give the formalized definition of extension resource [28]. Full excavation and utilization of extension resources is the important content in resource management and research.

1. Definition of extension resource

Set U as the resource universe of discourse of one enterprise, $u \in U$ refers to the enterprise's certain resource, $y=k(u)$ is the mapping of U to real domain which means resource u conforms to the degree required by the enterprise, $T=(T_U, T_k, T_u)$ is the transformation to be made, $y' = T_k k(T_u u)$ means the resource conforms to the degree required by the enterprise after transformation T, and the extension set on U about transformation T is

$$\tilde{E}(T) = \left\{(u, y, y') \middle| u \in U, y = k(u) \in I; T_u u \in T_U U, y' = T_k k(T_u u) \in I\right\},$$

thus when $T=e$, the positive resource domain of enterprise (i.e. the resource set conforming to enterprise requirement) is

$$E_+ = \left\{(u, y) \middle| u \in U, y = k(u) > 0\right\}$$

The negative resource domain of enterprise (i.e. the resource set not conforming to enterprise requirement) is

$$E_- = \left\{(u, y) \middle| u \in U, y = k(u) < 0\right\}$$

The resource zero domain of enterprise (i.e. the recourse set both conforming to and not conforming to enterprise requirement) is

$$E_0 = \{(u, y) | u \in U, y = k(u) = 0\}$$

When $T \neq e$, the extension resource of enterprise (i.e. the resource set that can change from not conforming to enterprise requirement to conforming to) is

$$\underset{\bullet}{E}_+(T) = \{ (u, y, y') | u \in U, y = k(u) \leq 0; T_u u \in T_U U, y' = T_k k(T_u u) > 0 \}.$$

The key to change the resource not conforming to enterprise requirement to conforming to is selecting transformation T to make $y' = T_k\, k(T_u u) > 0$. See detailed transformation method and constructor of dependent function in 2.4 and 2.7 of this book.

According to the ides of extension set, the key for changing the resource not conforming to enterprise requirement (e.g. negative resource, uncontrollable resource etc.) to an extension resource lies in finding a proper transformation. Extension resources of distinct types can be obtained through different transformations. Of course, different extension resources can be realized through the same transformation as well.

According to conjugation analysis method, resources can be classified into real resource, imaginary resource, soft resource, hard resource, latent resource, apparent resource, negative resource and positive resource. That is, considering from the materiality, resources include real resource (e.g. people, wealth, objects and other tangible properties) and imaginary resource (e.g. brand, famous people, technology, knowledge and intelligence of personnel and other intangible properties). Take power resource for example, the authority given by administrative department is real resource. Besides, like the prestige caused by human influence and reputation etc., this part of resources belongs to imaginary resource. Human resources have imaginary and real parts more obviously. For instance, people belong to the real resource of enterprise while the technology, knowledge, intelligence, relation and reputation of people are the imaginary resources of enterprise. Considering from the systematicness, some real and imaginary resources can also form each constituent part of an enterprise, i.e. the hard resource of the enterprise. The relation among each part and that between parts and outside world is the soft resource of the enterprise; considering from dynamics, there are latent and apparent resources; considering from the contrariety, there are negative and positive resources. If the enterprise runs well, latent resources will be changed as apparent resource. Both negative and positive resource can be utilized by the enterprise.

To achieve business goals, entrepreneurs must analyze various resources carefully and obtain long-term business profit through developing and utilizing different resources. Whether the resources not belonging to the enterprise can be changed to its usable resources is a subject which must be carefully studied by entrepreneurs.

2. Approach to find extension resource

Based on the concept of extension resource, it can be found according to different transformations therein.

(1) Extension Resource about Element Transformation

When $T_U = e$, $T_k = e$, call

$$\underset{\bullet}{E}_+(T_u) = \{(u, y, y') | u \in U, y = k(u) \leq 0; T_u u \in U, y' = k(T_u u) > 0\}$$

the extension resource about the transformation of element u.

Because element u is a certain resource and resources can be divided into internal and external resources, extension resources about element transformation can also be classified into internal extension resource and external extension resource.

1) The internal real resource of enterprise is its controllable resource, but lots of imaginary resource of enterprise is uncontrollable, e.g. the intelligence resource, technical resource and relation resource of employees. It requires the enterprise to take various incentive and promotion mechanisms to increase enterprise incentive and centripetal force, closely relate the employees' interest to enterprise profit, and fully play the employees' enthusiasm and creativity to make them completely contribute to the enterprise. For instance, one software company employed a software designer A. He had strong design ability while both the company's management and sale levels were very low, which made business profits cannot be raised. Later, the General Manager of the company found A not only had strong design ability but also had strong organizing ability and wide marketing network. Thus A was exceptionally promoted as the assistant of the General Manager and later promoted as the General Manager, which gave A enough space to exercise his talents and largely increase the business profits. From this we can see that enterprise internal extension resource is mainly the extension of latent resource in imaginary and soft resources. The latent resource is manifested through proper transformation and becomes the enterprise's usable resource.

Internal extension resource is mainly the mutual conversion of various internal resources. This conversion is realized through certain transformations.

2) External extension resource is the resource which is specially concerned by modern enterprises. So-called "extension resource" mainly refers to "external extension resources". External extension resource includes both real and imaginary resources, both hard and soft resources. E.g., through certain transformations (stock or interest etc.), use the capital of bank or other units as our own. This kind of resource is just external extension resource; through certain transformations (rent or exchange etc.), use the factory buildings and equipments of other related enterprises to produce products for ourselves. It saves much time and capital to invest to factory buildings and equipments. This kind of capital is just external extension material resource; through certain transformations (remuneration or exchange etc.), use the employees of external units to make product design and employee training for our own unit. This kind of resource is just external extension intelligence resource.

External extension resource can be realized through the conversion with internal resource or through other transformations. Of course, different extension resources can also be realized through the same transformation.

(2) Extension Resource about Universe of Discourse Transformation

When $T_u=e$ and $T_U U\text{-}U\neq\Phi$, $T_u\, u=u$,

$$T_k\, k(u) = k'(u) = \begin{cases} k(u)\,, & u\in U\cap T_U U \\ k_1(u), & u\in T_U U - U \end{cases}$$

call

$$\underset{\bullet}{E}_{+}(T_U)=\{(u\,,y\,,y')\,|\,u\in U\,,\, y=k(u)\leq 0;\ \ u\in T_U U\text{-}U,\ \ y'=k'(u)>0\}$$

the extension resource about universe of discourse transformation. All extension resources of this type are external extension resource.

The scope transformation of resources required for realizing business goals, i.e. transformation of universe of discourse, can also change external uncontrollable resource to extension resource. For instance, the resources considered by enterprises are mainly limited to domestic. In fact, many foreign resources can also be used by us.

In certain period, the resource universe of discourse of enterprise may be various resources in enterprise's location. With the development of business, finding extension resource in local region cannot meet the enterprise's needs. Thus the enterprise must make resource universe of discourse transformation, or replace, or increase and delete, or expand and reduce, or combine, e.g. expand resource universe of discourse to nationwide, or replace one provincial region with another region to adapt to the demand on enterprise development.

(3) Extension Resource about Dependent criterion Transformation

When $T_U=e$, $T_u=e$, $T_U U=U$，$T_u\, u=u$, call

$$\dot{E}_{+}(T_k)=\{\ (u,y,y')\mid u\in U, y=k(u)\le 0, y'=T_k k(u)>0\ \}$$

the extension resource about dependent criterion transformation. This kind of extension resource can be both external and internal extension resource.

The enterprise has different requirements on resources with distinct types in different development stages, i.e. dependent criterion can be different. E.g. for enterprise human resource, the former enterprise system cannot fully arouse the employees' enthusiasm, which leads to the employees' physical and mental resources that cannot be fully utilized, i.e. $k(u)\le 0$. Later, the enterprise makes a series of reforms, adopts taking up a job through competition, changes fixed wages as the combination of fixed wages and merit pay and increases the employees' welfare etc., which make the dependent criterion of employees and enterprise change, i.e. $T_k k(u)=k'(u)>0$ and then extend internal resource. For enterprise external human resource, recruitment, part-time job, paid technical service and many other means can be adopted, i.e. redefine dependent criterion. Make $T_k k(u)=k'(u)>0$ to get external extension resource.

(4) Extension Resource about Conductive Transformation

Suppose extension resource cannot be found through transformation $T=(T_U, T_k, T_u)$, then conductive transformation of certain transformations can be adopted to find extension resource.

(5) Extension Resource about Transformations' Operation

Suppose extension resource cannot be found through transformation $T=(T_U, T_k, T_u)$, then the operation of these transformations can be adopted to find extension resources, including product transformation, AND transformation, OR transformation, inverse transformation of several transformations.

5.4.4 Way to Business Innovation—Construct Sound Enterprise

The rapidly changed modern new technology revolution has profound influence on society and economy, which makes enterprise business environments constantly change. Market competition is increasingly fierce and gradually develops from product competition to the competition of enterprise capacity. Therefore, the enterprise must analyze itself completely, find its advantages from various aspects and find collaboration to improve its competitiveness. Reference [25] offers enterprise conjugation analytical method and the idea of constructing sound enterprises.

1. Conjugate analysis for an enterprise

Analyzing an enterprise according to conjugate analysis method can fully understand the enterprise and correctly analyze its merits and demerits. Then according to the mutual conversion of the conjugation part, take corresponding measures in time to strengthen the enterprise competitiveness.

(1) Imaginary and Real Parts

People, wealth, objects, capital, facility, land and other material parts are the enterprise's real part. Enterprise name, prestige, reputation, sprit and purpose etc. reflect enterprise image, which are the features of an enterprise's imaginary part. The non-material part of enterprise is called enterprise imaginary part, which are the intangible assets of the enterprise. Although different from land, building, equipments and other tangible assets which have concrete image, intangible assets play an important role for business operations.

Enterprise image refers to the cognition and evaluation of enterprise partaker for the manufacturer. When consumers purchase a commodity, they always select according to their impression on the manufacture while facing various brands when the quality, price and after-sale service are almost the same. Thus the enterprise must take planned operating methods to build enterprise imaginary part like enlarging tangible assets so as to make the value of enterprise imaginary part larger and larger.

Most enterprise decision makers pay attention to the construction of real part but have no full understanding of the accumulation of intangible assets and their increment value. With the constant development of market economy, the value of enterprise imaginary part becomes more and more obvious. The construction of imaginary part increasingly attracts the extensive attentions of business people.

(2) Soft and Hard Parts

An enterprise is composed of the Production Department, Sales Department and Financial Department etc. Both the enterprise and departments are called the hard part of the enterprise. All internal relations and external relations of the enterprise are called its soft part. The internal relations of the enterprise refer to the relation between enterprise operator and each department and employees, the relation among enterprise departments and the relation among employees etc. The external relations of the enterprise refer to the relation between enterprise and external departments, e.g. the supplier of raw material, retailer, customer, financial department, governmental department and even competitors etc. Certainly the relation between the enterprise and environment is also included.

As a Chinese saying goes, "Three cobblers put their wits together which was equal to Zhuge Liang, the master mind". It means three people can do a good job if they have good teamwork. On the contrary, if they have no good relation, then "Everybody's business is nobody's business". Therefore, if entrepreneurs want to strengthen enterprise cohesion, they must endeavor to keep good internal relations. Besides, the establishment of public relations is also very important. We all know an enterprise with rough sales channels, blocked logistics and bad financing capacity is bound to go bankrupt. Therefore, while constructing the hard part well, the enterprise must construct the soft part well, which is very valuable to business operations.

Enterprise function is the result of the combined action of an enterprise's hard and soft parts. Neglect of either aspect will bring loss to the enterprise.

(3) Negative and Positive Parts

For certain features, both the negative and positive parts of an enterprise are indispensable. Some negative parts are valuable and they make the employees create more profits for the enterprise. Some enterprises pay more attention to the construction of positive parts but consider less for the construction (or disposal) of negative parts as well as the proportion of negative and positive parts.

In the market economy, the construction of negative and positive parts should be proper. And the practice of building enterprise to "small society" should be changed. The negative part of our national enterprise is overlarge before reforming joint stock system, which makes the enterprise have heavy burden and cannot continue to develop. Thus the enterprise must pay most attention to the construction of positive part through reforms.

(4) Latent and Apparent Parts

The apparent part of the enterprise is called the enterprise apparent part. The latent but not manifested part is called the enterprise latent part, e.g. hidden danger, latent profits, sale potential etc. Much investment is needed in the initial construction stage of the enterprise. It may lose money, but the potential future profit is contained. As an entrepreneur, they should be good at seeing the latent part of the enterprise and timely find the hidden danger to nip it in the bud; they should also be able to find advantageous latent parts and manifest it. Large potential hides among the employees. Certain measures should be taken to manifest the potential and create wealth for the enterprise.

2. Transformations of enterprise's conjugate parts

According to conjugate transformation principles, the conjugation parts of an enterprise can be mutually transformed under certain conditions. Capable entrepreneurs are good at knowing the relations among each enterprise's conjugate parts to grasp the rules and methods of transformations and promote enterprise development.

(1) Transformations of Imaginary and Real Parts

The imaginary and real parts of an enterprise can be mutually transformed under certain condition. The change of imaginary part will cause the change of real part, vice versa. The enterprise hands its capital (real part) to television station and the television station transmit the enterprise and product image to consumers, which improves enterprise popularity (imaginary part). Then part of consumers purchase products of the enterprise at stores with money and the capital is handed over back to the enterprise through stores. This process is the conversion process of imaginary and real parts as shown in Figure 5.18.

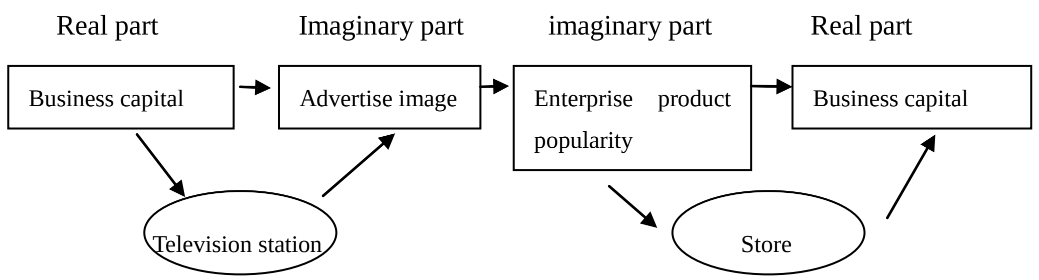


Figure 5.18 Conversion Process of Imaginary and Real Parts

The television station and stores play the role of conversion. In market marketing, being good at using these "converters" can make the enterprise obtain more profits.

(2) Transformations of Soft and Hard Parts

The soft and hard parts of enterprise can also be transformed under certain conditions. If enterprise principal or a leader of a certain enterprise department is changed, all internal and external relations of the enterprise or department will be accordingly changed. These changes will have great influence on business operations. The rules and regulations of enterprise and the change of public relations will also influence the change of enterprise. Therefore, to operate the enterprise well, we must pay attention to the arrangement of enterprise hard part and coordination of soft part. Entrepreneurs that can handle problems well sometimes start from the “hard” part and then resolve contradiction through personnel alternation; sometimes they start from the “soft” part to make the centripetal force and cohesion produced inside the enterprise through relation adjustment.

(3) Transformations of Negative and Positive Parts

The negative and positive parts of an enterprise can be mutually transformed as well under certain conditions. The improvement of the enterprise welfare (negative part for profits) will raise the employees’ enthusiasm for labor (positive part for profits); the improvement of enterprise output (positive) will, accordingly, increase the three wastes (negative). And administrative expense must be increased or make comprehensive utilization.

The products of enterprise earn profits for the enterprise, but “the three wastes” must be disposed with money. Some enterprises reuse the processed wastewater through comprehensive utilization and change waste residue to bricks so as to transfer negative part to positive part. Besides, good disposal of “three wastes” also eliminates the “hidden danger” of the enterprise, for enterprises without considering social interest are bound to be eliminated.

The transformations of negative and positive parts need certain conditions, but smart entrepreneurs will use these transformations to obtain profits.

(4) Transformations of Latent and Apparent Parts

Under certain condition, the latent part of an enterprise will be transformed to apparent part. These manifestations may be favorable to the enterprise. For instance, the transformation of latent profits to realistic profits and transformation of employee potential to working enthusiasm will improve production efficiency. However, they may be unfavorable. For instance, the accumulated anger of employees will be transformed to slowdown and even damage at certain degree. Hidden dangers will be transformed to accidents at certain degree. Therefore, we should strengthen apparent conditions to manifest the favorable latent part of the enterprise. We should also reduce latent conditions to avid manifestation for unfavorable latent part. For unfavorable apparent part of the enterprise, latent conditions should be increased to manifest it. The transformations of enterprise latent and apparent parts are as shown in Figure 5.19.

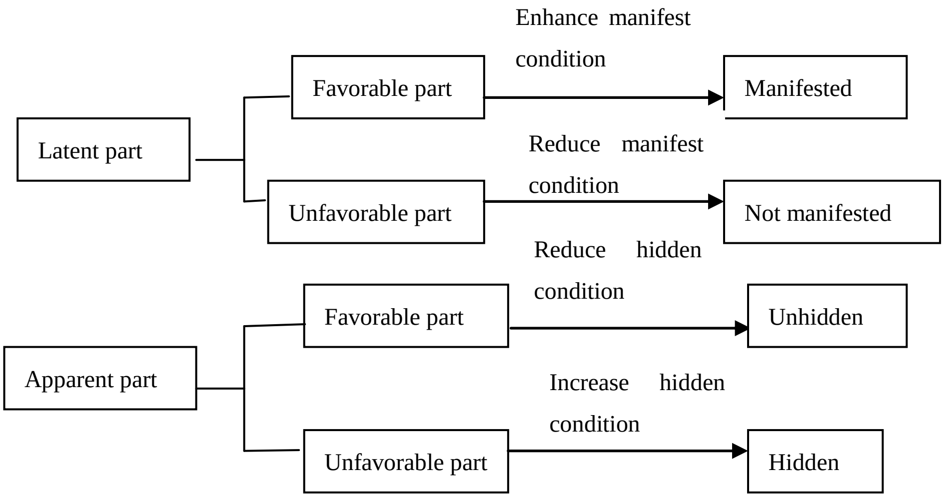


Figure 5.19 Transformations of Enterprise Latent and Apparent Parts

3. Construct sound enterprise

The so-called sound enterprise refers to the imaginary and real parts, soft and hard parts of the enterprise are rationally coordinated; the positive and negative parts favorable to enterprise development can be rationally constructed; the positive and negative parts unfavorable to enterprise development should be reduced; the latent part can be found; promote the manifestation of enterprise latent part and prevent the manifestation of unfavorable enterprise latent part. Sound enterprise is expected to develop to famous brand enterprise.

(1) Enterprise's Conjugate Analysis and Concept of Sound Enterprise

Traditional business concept only considers the visible entity of enterprise and pays attention to controllable business resources. For enterprise capacity, only human resource, material resource and financial resource are seen, which has certain one-sidedness. From the perspective of Extenics, all enterprises have imaginary and real parts, soft and hard parts, latent and apparent parts, negative and positive parts. To analyze an enterprise, we cannot only see its real, hard and positive parts but also see its imaginary, soft and negative parts; we should not only see its apparent part but also see its latent part, including latent and danger. The analytical method is called enterprise conjugation analysis.

To establish sound enterprise, we should make extensible analysis of the enterprise capacity and resource first. Then we should make conjugation analysis of the enterprise to find the merits and demerit of the enterprise capacity, resource and each conjugation part (compared with competitive enterprise). Then we should select the reform of organizational form to choose one organizational form adjustable to the enterprise competition and improvement of the enterprise competiveness.

Sound enterprise is a dynamic concept, which is the permanent objective of the enterprise.

(2) Organizational form of Sound Enterprise

The organizational form of sound enterprise can be traditional enterprise organizational form or decentralized enterprise, cross enterprise, virtual enterprise etc. That is to say, enterprises with various forms can be established to sound enterprises. Take virtual enterprise for example its basic sprit lies in the complementary capacity of breaking through the enterprise limit and separating positions through borrowing "external resource integration". When respective positions are kept unchanged, integrate a kind of cohesive productivity resource. Virtual enterprise is a kind of dynamic alliance used for making quick respond to market environment. Its virtuality lies in: its departments or functional organizations are not as complete as a normal enterprise. But it is really an enterprise and exercises all its functions through virtual alliance (no matter those functions come from external cooperation and assistance, or use internal functions). Besides, it can finish the preset objective more efficiently with low cost and high quality.

(3) Analyze Virtual enterprise from Extenics Perspective

Virtual enterprise has both imaginary and real parts, as well as various conjugation parts. To make virtual enterprise become sound enterprise, its real and hard parts must be few and delicate. Realize the integration of internal, external extension resources and enterprise controllable resource as well as the integration of extension markets of each sub-organization of the enterprise through the extension and transformation of imaginary and soft parts. A sound virtual enterprise must have a strong and powerful enterprise core. The core and other parts of the organization increase the external scale displayed to customers or geological coverage of the competitor through sharing facilities, resources or core capacity; adapt to the competition through sharing risks and cost of infrastructure; carry out product or service ideas through sharing brand, market and customer loyalty so as to seize operating opportunities; relate complementary core capacities through sharing and shortening the time form "concept $\rightarrow$cash"; from product marketing to sales program, cooperate to complete respective ordered work of competitors and even unaccomplished task under cooperative conditions.

5.5 Extension Planning Method

Planning is both a science and an art. Planning, in many cases, is made for resolving contradictory problems, and creative thinking needs to be fully used. Starting from the angle of resolving contradictory problems, the planning we made with extension methods is called extension planning. As the outcome of combination of Extenics and Planning, it tells people the way to generate the planning idea of “making infeasible feasible”, “changing opposite to coexist” with formalized method when contradictory problems occur, as well as the way to find extension resource to resolve the resource problem in planning.

In 2002, the monograph *Extension Planning* [28] was published by Science Press as one of the “Extenics Series”. This section will give a simple introduction to the basic ideas and theories of extension planning and detailed introduction of its basic methods. It will also illustrate the practical operation of extension planning with examples. See detailed content in reference [28].

5.5.1 Basic Ideas for Extension Planning

Since the emergence of human beings, planning is closely related with human behaviors. To enhance the purposiveness and effectiveness of behavior, we’re making all kinds of planning at every scale of time and space. It can be said that the purposiveness and effectiveness of human activity are just the root causes for planning. The progress of human society is actually a process of constantly resolving various contradictory problems. Especially in the current new economy era, the competition becomes fierce and the internet narrows the space and time differences increasingly. The average life of products and enterprise is shortened continuously with various complicated contradictions. Therefore, it is necessary to make planning from the angle of analyzing and resolving contradictory problems so as to find their rules and formalized methods to break through the limitation of traditional planning mode and make planning more scientific, standard, ordered and reasonable, which can promote the popularity and expansion of planning.

There are all kinds of planning. Whatever planning forms, they all aim to achieve certain objectives. Among all planning, there are all kinds of contradictory problems. How to change “infeasible to feasible” and “opposite to coexist” are the difficulties in planning. If the planner grasps the rules and methods to change “infeasible to feasible” and “opposite to coexist”, the difficulties of planning will be easier to be dealt with. Basic ideas of extension planning mainly have following points:

1. Extension idea of “Kill Two Birds with One Stone”

All planning involve many lots of objects. According to the extensible analysis principle in Extenics, any object can have many characteristics and one characteristic can be possessed by many objects; to finish one thing, lots of things are often needed as the basis; to do one thing usually causes many related things to happen. If all things caused by one thing have favorable effects, it can be called “achieve many things at one stroke”. “Multi-purpose”, “kill two hawks with one arrow”, “kill two birds with one stone”, “peel off five skins from one cow” are all representations of this idea. To apply these ideas in planning can half the work with double results.

2. Extension resource’s idea of “Do Your Things with Others’ Resources”

In traditional resource based view, the enterprise always pays attention to controllable resources of its own. This kind of thinking mode decides our use form as “make ends meet”. However, resources with large quantity and various types (usable resources) are needed in business operations, which exist in society and nature extensively.

The resources not belonging to an enterprise but can be used by the enterprise after certain transformations are called the extension resource. Based on the idea of extension resource, the planning doesn't focus on the enterprise's controllable resources but adopt the thinking mode of "make end meet". Arrange various transformations according to the resources needed for the planning. Change controllable resources needed by but not belonging to the enterprise to extension resources. Integrate various required usable powers as usable powers of the enterprise. Do larger things with fewer resources.

In planning, to understand "rely on others for success in work" is more important than relying on ourselves while the result is equal to self-development. If we hope to succeed in shopping mall, we should be able to skillfully use extension resources to create profits. Extension planning is a practical activity that can skillfully coordinate to use extension resources to create new value. Therefore, finding and extending extension resources effectively with rational allocation is the key idea in extension planning.

3. Idea of innovation unlimited

The concepts of extensibility and extension set of things provide many optional ways, methods and ideas to us to resolve contradictory problems. However, these ways, methods and ideas must be adopted after selection. The selection aims to eliminate the false and retain the true, eliminate the demerits and retain the merits. In the process of selecting, conditional restrictions and system compatibility must be considered.

Extenics thinks all programs are imperfect, extensible and improvable. For program selection, only better solution can be obtained. Besides, because things develop and change continuously, no program should be absolutely fixed. They should be constantly adjusted with the development of situation and course of time. Even current better solution may be eliminated later.

The opinion of "All programs are imperfect" refers to the idea of innovation unlimited, which is especially important to decision makers. It can make decision makers unsatisfied and pursue higher realm permanently. It can also make decision makers implement the planning with developing vision and constantly adjust while implementing the planning to make the result of implementation surpass the preset objective.

4. Assisted planning with new tools in information era

Planning is a high-level and complicated rational thinking activity. The core of this activity is creative thinking, which runs through the whole planning process. The essence of planning is innovation and seeking change. The planning without creative thinking is only a rigid dogma.

Creative thinking is the overall understanding and grasp of the essential attributes and internal relations of planning objects. It is very important in planning process as the largest difficulty for decision makers. While creative thinking isn't ridiculous and aimless, it has rules to abide by. We can make formalized description and analysis of creative thinking to break the mystique around and create conditions for assisted planning with modern information technology.

5.5.2 Basic Theories of Extension Planning

Based on the current trend of insufficient theoretical research in planning, we can study the basic theories of extension planning according to the basic theories of Extenics, including the extensible analysis principle of planning goal and condition, transformation in extension planning and its integration principle, conjugation analysis principle of things involved in the planning and the dynamic transformation principle of extension planning, to give common creative thinking modes in extension planning and lay the theoretical basis for planning activity.

1. Extensible analysis principle of planning goals and conditions

Extensible analysis principles include divergent analysis principle, correlative analysis principle, implication analysis principle and opening-up analysis principle. These principles are the basis for formalized analysis of planning goals and conditions expressed with basic-elements according to the divergence, correlation, implication and opening-up of affairs, matters and relations. Because both the subject and object of planning, planning goals, planning conditions and planning object are extensible, they can help people understand and apply extension methods to resolve the contradictory problems in planning after the formalized representation with basic-elements so as to expand our idea for solving contradictory problems.

2. Transformations and integration principles in extension planning

According to the extensible analysis principle of planning goal and condition, we can get various ideas for resolving contradictory problems. However, to form the planning idea for resolving contradictory problems, we must realize it through various transformations and integrations. The objects involved in the planning include planning goals, planning conditions, planning subject, object and resource etc., all of which can be transformed and integrated.

Transformation is a means for solving contradictory problems. According to the concept of extension transformation and basic extension transformation in Extenics, we studied the transformation principles and integration rules obeyed by objects involved in extension planning, which offers formalized tool to generate planning idea.

3. Conjugate analysis principle of objects involved in planning

In Extenics, we classify objects into imaginary and real parts, soft and hard parts, latent and apparent parts, negative and positive parts from four aspects including materiality, systematicness, contrariety and dynamics. All objects involved in the planning have the conjugate parts. We studied conjugate analysis principle and conjugate transformation principle, which offers the theoretical basis for solving contradictory problems in planning through conjugate analysis. In extension planning, conjugate analysis is mainly applied to resource analysis.

4. Dynamic transformation principle in extension planning

To represent the change process of things more accurately and quantitatively, especially how things can be transformed from “without certain property” to “with certain property”, or how to transform “incompatible to compatible” “opposite to coexist”, to make the planning activity more scientific, we give the dynamic transformation principle of things in extension planning according to the concept of extension set.

5. Creative thinking mode in extension planning

From the perspective of Extenics, all objects are extensible and transformable. The application of ideas and methods for dealing problems in Extenics in human thinking field is quite proper. It resolves problems like “how to innovate”, “from where to innovate” and “how to evaluate the results of creative thinking” etc. Just based on this, we propose four creative thinking modes, i.e. rhombus thinking mode, reversed thinking mode, conjugate thinking mode and conductive thinking mode and give formalized representation to help people solve contradictory problems with these thinking modes.

5.5.3 Basic Methods for Extension Planning

Planning is a kind of activity with strong purpose. All planning are made to resolve a certain problem of an organization. Based on the opinions in Extenics, all problems are composed of the goal and the condition. The major problem to be resolved in extension planning is how to change incompatible problem to compatible problem and how to change opposite problem to coexisting problem.

According to the extension models of contradictory problems in Extenics, all contradictory problems in planning goal, condition and planning can be represented with extension models. Starting from the establishment of extension models of contradictory problems, we can get the related, implied, divergent and extensible information of problems to be resolved through extensible analysis with formalized method. Trough conjugate analysis, we can fully understand the merits and demerits of objects involved in the planning. Generate various ideas for resolving contradictory problems with extension transformations or transforming bridge method. Then for these generated ideas, evaluate and select according to concrete problems to choose those with higher superiority as the ideas for drawing up planning program.

Define and modeling the problems. Make extensible analysis of planning goal and conditions. Make conjugate analysis of resources and generate planning ideas with extension transformation methods or transforming bridge method. All these are basic methods in extension planning. See corresponding extension methods in this book for reference.

This section mainly introduces the methods of generating planning ideas that can change incompatible problems to compatible ones and those can change opposite problems to coexisting problems. Therefore, extension planning ideas will be introduced first.

1. Extension planning idea

Extension planning is the planning starting from analyzing contradictory problems. Its ideas are bound to be generated based on the contradictory analysis of planning theme, object or subject.

The generation of ideas is a creative thinking process which obeys "rhombus thinking mode", i.e. the mode of "divergent first and convergent later". Its divergent process is generally considered as difficult to grasp without rule to abide by. In fact, we can form various innovative ideas after proper problem definition through extensible analysis and transformation with formalized method and even computers. It is a very feasible formalized method for divergent process and helps decision makers to generate planning ideas a lot.

If a great idea cannot be realized, it will become a reverie. Lots of planners try to think of good ideas according to their own planning practice with brave breakthrough. But after the ideas are generated, we should also consider whether they are feasible, i.e. evaluating and convergence process of ideas. It is both an indispensable process and a process that cannot be assumed subjectively. It can be confirmed only after the scientific evaluation and selection of measuring conditions according to the analysis of resource condition and other conditions. Many planners often neglect resource and environmental restrictions and confirm ideas without careful evaluation. Then the phenomenon of insufficient reserve force occurs when the planning is halfway through, which leads to the failure.

Therefore, "good" ideas are definitely important, but "feasible" ideas are more important. On the premise of being practical, "feasible" ideas are always better than the "best" ideas.

The generation of extension planning ideas pays special attention to the combination of divergence and convergence, for ideas are the soul of planning. Only feasible and special ideas are formed can the planning be guaranteed successful.

The generation of planning ideas and analysis and integration of resources are two key links in planning process. Theories and methods in Extenics reveal the internal rules of these two key links and raise the formalized new idea for resolving contradictory problems. Then the habitual domains of the planner are changed and we needn't make planning with inspirations. Meanwhile, the formalized description of objects in Extenics carves out a way to apply information technology to planning process, which makes sure that planning can be more scientific, systematic, feasible and effective and offers important guarantee for correct decision.

The method of generating extension planning ideas is a formalized, operational, quantitative and qualitative method. It adopts the formalized presentation in Extenics to represent the creative thinking process of generating ideas with signs. Because there is large amount of information ideas are generated, complicated problems cannot be completed only with the imagination of human brain or notes. The method of generating extension planning ideas can be adopted to complete the extension, transformation and evaluation process with the help of computers.

2. Generation and evaluation method of planning ideas for transforming incompatible to compatible

For incompatible problems, based on obtaining various ideas for resolving incompatible problems after the extensible analysis of planning goal and condition and conjugate analysis of resource, to transform incompatible problems to compatible ones, we must make extension transformations to generate various planning ideas. Then adopt proper evaluation method to select the ideas and confirm one or several feasible planning ideas. The steps for generating planning ideas that can transform incompatible problems to compatible ones are as follows:

(1) Define Contradictory Problem

Defining problems accurately is the basis for resolving problems. The planner should "define problems" for clients first to make them simple and explicit for judging their significance. To define problems accurately for clients is a key to successful planning.

To define the problems, we should define the goal and condition first. Then we should establish the extension models of the problem and the core problem based on different situations of panning goal and conditions as well as the way to establish problem extension models so as to define the contradictory problems to be resolved accurately. If one problem is an incompatible problem, then go to the next step.

See the method of defining problems in 4.1 of this book.

(2) Make Extensible Analysis of Planning Goals and Conditions

Make extensible analysis of the planning goals or conditions represented with basic-elements with extensible analysis method. In extension planning, the most popular is divergent tree method, correlative net method and implication system method. Analyzing planning goal or conation with extensible analysis method can find various ways to resolve contradictory problems. See 3.1 of this book for reference.

(3) Resource's Conjugate Analysis Method

Contradictory problems are usually formed due to the limitations of resource condition. Therefore, we should make resource's conjugate analysis to distinguish what resources leads to the contradiction, what's the resources advantage of planning subject, whether resources' conjugate transformations can be used to change resources disadvantage to advantage, and how to solve contradictory problems with favorable resources etc.

What should be especially pointed out is that resource's conjugate analysis isn't made in the extension planning of all fields or not all conjugate analyses analyze resources from materiality, systematicness, contrariety and dynamics. We should make targeted resource analysis based on the type of contradictory problems formed by planning subject and resource types involved. It can also avoid distracting. See also 3.3 of this book for reference.

(4) Generate Several Ideas with Extension Transformation Method

According to different practical problems, distinct extension transformations of planning goal or condition can be implemented to generate planning ideas for resolving contradictory problems. Besides, the range of objects involved in the planning can be changed as well. Sometimes even the dependent criteria of objects can also be changed. Therefore, the transformation of universe of discourse or dependent criterion can also be selected to generate planning ideas for solving contradictory problems.

In concrete application of extension transformation methods, sometimes the purpose of solving contradictory problems can be achieved with basic extension methods only. While sometimes we should use transformation combination to achieve the purpose. Besides, the conductive transformations caused by the transformation in implementation should be paid special attention to. We should consider that its effect is positive or negative to avoid adverse consequences. See detailed transformation methods in 3.2 of this book.

(5) Evaluate and Select Above Ideas to Choose Feasible Planning Ideas

Several different ideas can be got with different transformation methods. But not all ideas are feasible and can achieve good effects. Thus we must select certain evaluation methods to evaluate and sift above ideas to select the better ones as the ideas for forming planning program. Besides, one idea may generate several planning programs, or planning programs respectively generated by several ideas with similar superiorities are also decided through evaluation. The evaluation of planning ideas or programs refers to comprehensive evaluation with several indexes. There are many multi-index comprehensive evaluation methods, e.g. common multi-index comprehensive evaluation method, fuzzy comprehensive evaluation method, multivariate statistics comprehensive evaluation method etc. They have their own merits and application fields. While evaluating planning ideas or program, a certain method above can be selected to evaluate. These methods are discussed in many articles in details, thus there is no introduction here. The superiority evaluation method introduced in3.5 of this book also applies to the evaluation of planning ideas and programs.

(6) Form Planning Program

After selecting ideas with higher superiority with superiority evaluation methods, we can enter the process of forming planning programs. For several formative planning programs, we can use above evaluation methods to evaluate and select. But the measuring condition and dependent function should be accordingly changed based on concrete circumstances. Finally confirm 1~2 planning programs to provide for decision makers or entrusted planning unit.

After confirming planning program, we can enter the stage of implementing the planning. In the process of implementation, we should also pay attention to evaluate the practice effect. This evaluation is also very important, for it is the evaluation made from the angle of ultimate practical performance, which can reflect the effectiveness of planning. Thus in planning implementation process, we should establish an information feedback system to follow and verify the implementation situation. For the situation of deviating from planning goal, we should get information feedback in time so as to take measures to correct. If the original planning program is found wrong, or major changes occur in subjective and objective conditions through information feedback and the original is difficult to be continuously carried out, we must follow the planning to make fundamental revision and adjustment of the original planning goal and program.

There are many methods of evaluating the effectiveness of planning program, e.g. questionnaire method, symposium method, ratio analysis approach, difference analysis method etc. For different planning contents, distinct methods can be selected to evaluate. Interested readers can see related planning books for reference.

Thus it can be seen there are three links required to be evaluated while making extension planning: ① Selection of planning ideas; ② Selection of planning program; ③ Evaluation of planning practice effect. All these three links can be evaluated with superiority evaluation method. Of course other methods can be adopted as well case by case.

See the flow of extension planning for solving incompatible problems in Figure 5.20.

3. Generation and evaluation method of planning ideas for transforming antithesis to coexist

Transforming bridge method is the method of connecting both rival sides and transforming them as coexist with the idea of “Everything is in its right place” though setting up a transforming bridge.

The transforming bridge is composed of a transforming part and a transforming passage. To construct the transforming bridge to deal with antithetical problems, the key lies in the way to construct the transforming part and transforming passage. The transformation to generate the transforming part and transforming passage to solve antithetical problems is just the planning idea to transform antithesis to coexist.

The steps for the method of generating and evaluating planning ideas that can change antithesis to coexist are similar to the steps for the method of generating and evaluating planning ideas that can change incompatible to compatible. No detailed description here. See 4.4 of this book for reference.

The flow of extension planning for solving antithetical problems is as shown in Figure 5.21.

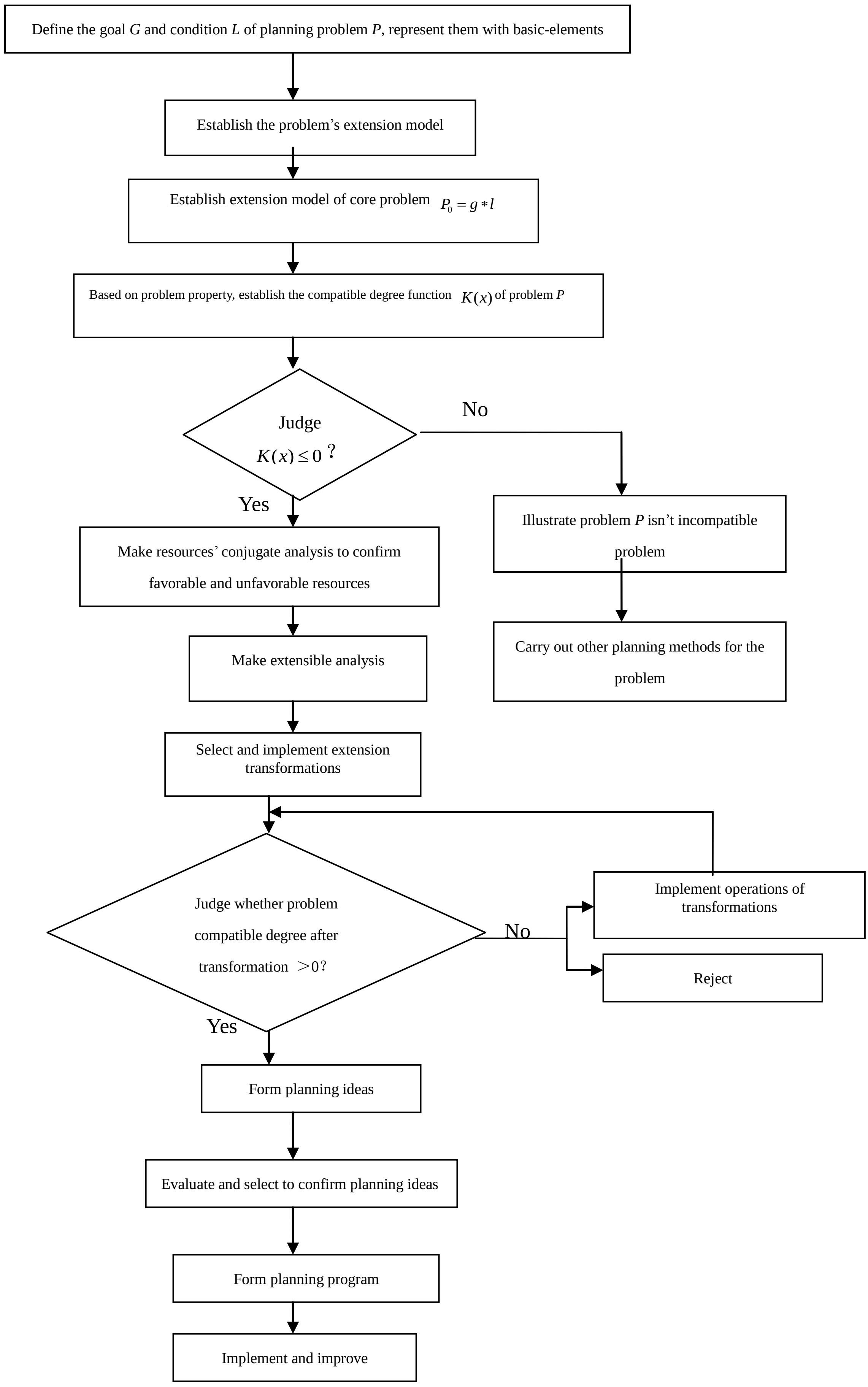


Figure 5.20 Flow of Extension Planning for Solving Incompatible Problem

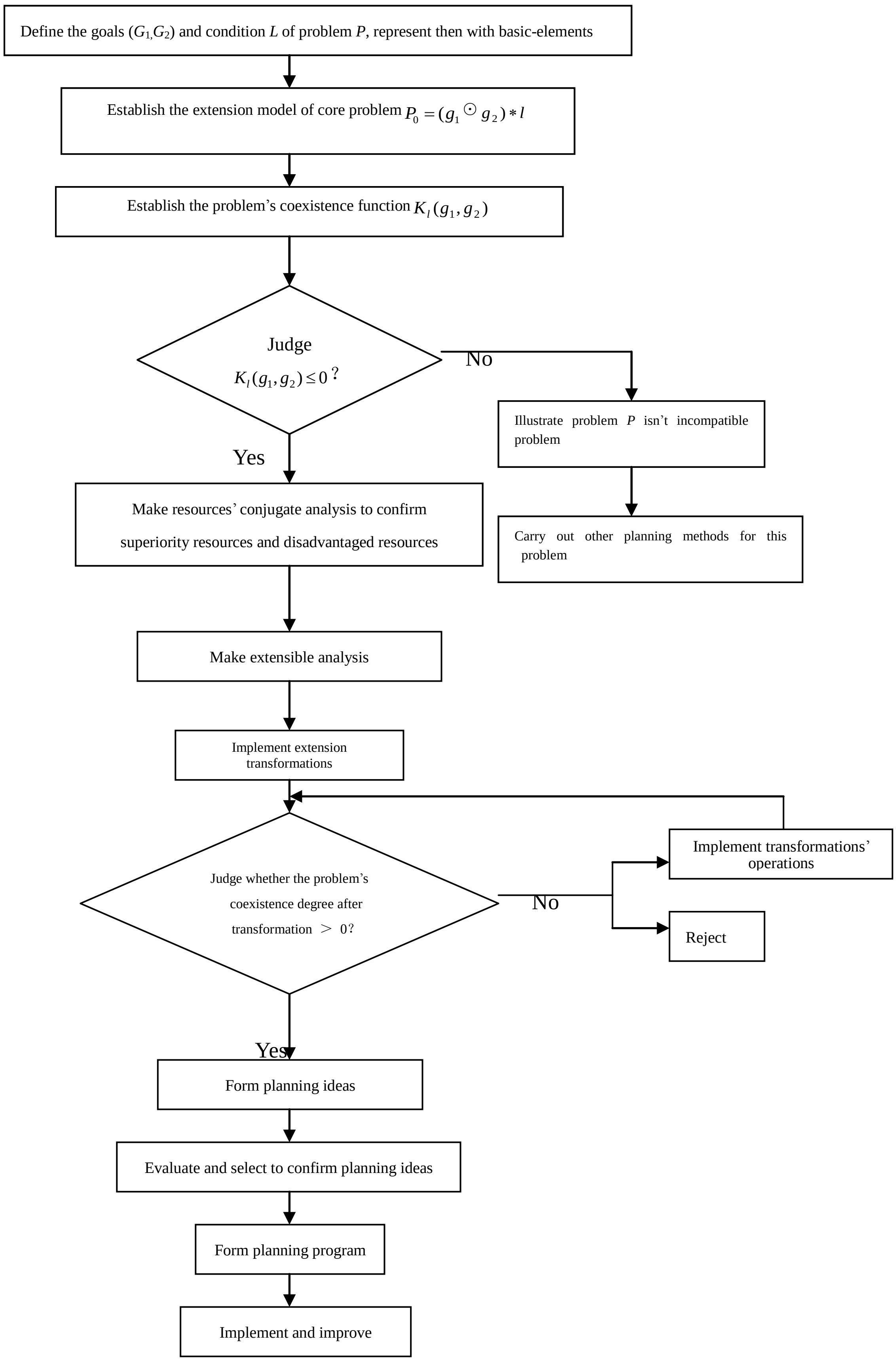


Figure 5.21 Flow of Extension Planning for Solving Antithetical Problems

5.5.4 Practical Operation of Extension Planning

The proposal of extension planning has important significance to the development of planning science and Extenics. It also provides the theoretical basis and operational method for planning and has good practical values for business planners to use modern scientific means to make scientific planning.

No matter what kind of planning practice, extension planning method can be adopted if we start with contradictory problems. Following extension planning practices are mainly introduced in monograph [28]:

1. Extension planning of resource integration

Resource integration, also called resource allocation, is a problem involved in any economic activity. The concept of resource evolves from traditional natural resource to various resources divided with the mode of conjugate analysis. The connotation and extension of the resource becomes wider and wider, and also more and more difficult to be grasped. The core of resource integration is making reasonable transformation and allocation of various resources to become the resource required to resolve a certain problem and realize maximum resource effectiveness.

The extension planning of resource integration mainly studies how to integrate various resources with our own resource advantage and find extension resources to reach the aim when resource contradiction occurs. To generate resource integration ideas, we should make conjugation analysis of our own resource first and then expand the resource with resource extensibility. Then make resource transformations with extension transformations, transformations' operations and conductive transformations to generate several ideas for resolving resource contradictory problems and confirm proper integration ideas that can realize maximum resource effectiveness through evaluation and selection. Finally generate the planning program of resource integration.

2. Extension planning of project

Project planning is an integral logistics planning made to projects proposed to be completed on three levels including strategy, tactics and operation so as to make sure to achieve project goal under various constraint conditions. Project's extension planning means to apply the basic ideas, theories and methods in Extenics to project planning, study how to expand project goal, restraint conditions and resources with extension methods and deal with the contradictory problems occurred in project planning.

The implementation of any project will produce large indirect effects besides the direct effect, For instance, the completion of one expressway will greatly promote the economic development of neighboring regions besides directly pushing forward transportation industry. Therefore, how to expand project effects based on obtaining preset direct effect while implementing a project is a problem that project planners should pay attention to and consider during planning.

To understand the problem of expanding project effect from the perspective of Extenics refers to pursue the problem of one-order, two-order and even multi-order positive conductive effects. Interested readers can make an intensive study on this problem.

3. Extension planning of market development

From the perspective of marketing, the market of a certain product is composed of all potential customers with certain needs or desire, willing and being able to meet the needs or desire through transformation. Therefore, the size of market relies on all people who have certain needs, possess the resources that can attract others and would like to exchange the resources with what they need. In short, all consumers that are capable and willing to buy certain product from the market of this product, which is also called marketing market. We have made formalized analysis of this market set with the idea of extension set and regard the concept of extension market as the basic basis for making the extension planning of market development.

The extension planning of market development mainly includes: study of consumer demand, orientation of product function, generating the planning ideas of extension market with extensible analysis method and extension transformation method etc. See related content in reference [28] and the section of extension marketing method in this book for reference.

4. Extension planning of crisis prevention and control

The representation forms of crisis are quite different. But essentially all crises are the results of various contradictions among the internal elements of objects and among things. If there is no contradiction, no crisis will exist. The breakout of crisis is the representation form of objects from quantitative to qualitative. In this stage, both the huge destructiveness of crisis represented by lots of incontrollable things, anomie, chaos and disorder and potential opportunities represented by various contradictory factors in dynamic cataclysm. Therefore, crisis prevention and disposal are a process of avoiding, appeasing, conciliating and resolving contradictions, i.e. the way to avoid intensifying contradiction. While when contradictions are intensified, how to reduce the loss caused by crisis to the greatest extent and how to expand and use potential opportunities in crisis. The process of conciliating and resolving contradictory problems expands broad space for applying extension planning ideas, theories and methods in it.

See the detailed study of related extension planning practices in reference [28].

Now let’s illustrate the application of extension planning methods with a planning case to help readers study and make further research and application.

[Example 5.3] One mountain village *N* is located at an extremely remote mountain area with rugged road, inconvenient transportation, and small agricultural acreage without any cultural landscape. Many young people go to other places to work, i.e. the idea of going out to earn money. But it leads to many young people never come back after going out. At present, the labor force left in the village only takes up 5% of total labor force, which makes the village at the poor and backward state. However, the village is with fresh air and thick trees. Then how to make the village get rid of poverty? Some people propose to develop livestock breeding and others suggest developing handcraft industry, but neither can become the dominant project of the village.

Now let’s generate the planning program of “achieve rich village” project with extension methods.

(1) Confirmation of project objective

In this case, project goal can be represented with matter-element formally as:

$$G_0 = \begin{bmatrix} \text{Village}N, & \text{per capita annual income}, & <10000,15000> \text{Yuan} \\ & \text{Labor force left}, & 40\%a \end{bmatrix} = \begin{bmatrix} G_{01} \\ G_{02} \end{bmatrix}$$

Thereinto, *a* refers to total labor force in the village.

(2) Confirmation of project condition

Confirm project conditions based on the project goal. In this case, the project goal is to make village *N* becomes rich. However, the conditions in the village are per capita annual income of 1,000 yuan, remote location, rugged road, inconvenient transportation, small agricultural acreage, rich forest resource without any cultural landscape, the left labor force takes up 5% of total labor force. They can be represented with a matter-element as:

$$L_0=\begin{bmatrix} \text{Village}N, & \text{per capita annual income}, & 1000\text{Yuan} \\ & \text{road condition}, & \text{rugged} \\ & \text{cultural landscape}, & \text{insufficient} \\ & \text{capital condition}, & \text{little} \\ & \text{job opportunity}, & \text{bad} \\ & \text{agricultural acreage}, & \text{small} \\ & \text{forest resource}, & \text{rich} \\ & \text{left labor force}, & 5\%a \end{bmatrix} \triangleq \begin{bmatrix} N, & c_1, & v_1 \\ & c_2, & v_2 \\ & c_3, & v_3 \\ & c_4, & v_4 \\ & c_5, & v_5 \\ & c_6, & v_6 \\ & c_7, & v_7 \\ & c_8, & v_8 \end{bmatrix} = \begin{bmatrix} L_{01} \\ L_{02} \\ L_{03} \\ L_{04} \\ L_{05} \\ L_{06} \\ L_{07} \\ L_{08} \end{bmatrix}$$

(3) Establishment of problem extension models

According to confirmed project goal and conditions, establish the extension model of the problem. Then confirm the contradiction type of the problem.

The extension model of the problem in this case is:

$$P = G_0 * L_0$$

with per capita annual income c_0 as evaluation characteristic, set

$$g=[N,\quad c_{0s},\quad <10000,15000> \text{Yuan}],\ l=[N,\quad c_{0t},\quad 1000\text{Yuan}]$$

Thus, the extension model of core problem of P is

$$P_0 = g*l=[N,\quad c_{0s},\quad <10000,15000> \text{Yuan}]*[N,\quad c_{0t},\quad 1000\text{Yuan}]$$

Establish the function of compatible degree

$$k(x)=\frac{x-1.0}{1.5-1.0}=\frac{x-1}{0.5}=2(x-1)$$

Obviously, the compatible degree of this problem is

$$K(P)=k(0.1)=2(0.1-1)=-1.8<0$$

Therefore, this problem is the incompatible problem of current conditions and goal of "becoming rich", i.e. $G_0 \uparrow L_0$ means to make villagers not go to other places to work but improve living standards under current natural conditions is an incompatible problem. To resolve this contradictory problem, we must extend and transform the goal and conditions.

(4) Resources' conjugate analysis

The real resources of village N are trees, villagers, mountain land and fresh air. Imaginary resources are original natural landscape and quiet environment. The residence of villagers is self-made wooden house with local materials. Inconvenient transportation leads to fewer human communication and the village is far away from modern civilization. However, people in cities are tired of their busy life and dream of an original and natural life. Therefore, the imaginary resource "original natural landscape" of this village becomes the focus of resource development.

(5) Extensible analysis of incompatible problem

1) Based on resource advantages of the village, make divergent analysis of condition L_0

$$L_0 \xrightarrow{\text{One-matter, multi-characteristics}} | \; L_1 = \begin{bmatrix} \text{village}N, & \text{air condition,} & \text{fresh} \\ & \text{natural landscape,} & \text{original} \\ & \text{greening condition,} & \text{good} \end{bmatrix}$$

$$\text{——} \,|\, L_2 = (\text{village}N, \quad \text{landscape feature,} \quad \text{priginal and natural})$$

$$L_2 \xrightarrow{\text{One characteristic-element, multi-matters}} | \; L_3 = (N_1 \hat{\subset} N, \quad \text{landscape feature,} \quad \text{original and natural})$$

$$L_3 \xrightarrow[L_{03}]{\text{One-matter, multi-charactistics}} | \; L_4 = \begin{bmatrix} N_1 \hat{\subset} N, & \text{feature,} & \text{unique} \\ & \text{development fund,} & \text{little} \\ & \text{Capital required,} & \text{existing} \end{bmatrix}$$

That is, to achieve the goal, one "original, natural and unique" consumer site N_1 that can use existing resources of the village with less development fund needs to be constructed.

2) Make implication analysis of goal G_0

$$G_0 = \begin{bmatrix} \text{Village}N, & \text{per capita annual income,} & <10000,15000> \text{Yuan} \\ & \text{left service people,} & 40\%a \end{bmatrix} = \begin{bmatrix} G_{01} \\ G_{02} \end{bmatrix}$$

$$\Leftarrow G_1 = \begin{bmatrix} N_1 \hat{\subset} N, & \text{attraction,} & \text{large} \\ & \text{investment,} & \text{small} \\ & \text{staff,} & \text{villagers} \hat{\subset} N \\ & \text{consumer,} & \text{external people} \end{bmatrix}$$

That is, to achieve G_0, we only need to realize inferior goal matter-element G_1. From the analysis we can see that if a consumer site N_1 with large attraction and less investment (considering the village's endurance) is created to attract external people to consume in the village, job opportunities can be created to improve the villagers' living standards.

For condition L_4 extended by (1), the core problem of problem $P_1 = G_1 * L_4$ is

$$P_0' = g' * l' = [N_1 \hat{\subset} N, \quad \text{investment required} \quad c_{0s}', \quad <50000,80000> \text{yuan}] * [N, \quad \text{investmetn offered} \quad c_{0t}', \quad 100000\text{Yuan}]$$

Obviously, $G_1 \downarrow L_4$. Therefore, the key problem below is how to design a consumer site that satisfies L_4.

From the resource analysis and divergent analysis of village N, we know it is feasible to start from its advantageous "original and natural landscape" to make full use of existing resources and generate planning ideas.

(6) Generating method of planning ideas

According to the divergent analysis of "one-value, multi-matters":

$$L_2 = (\text{village} \;\; N, \quad \text{landscape feature,} \quad \text{original and natural})$$

$$\text{—}| L_2' = [\text{villagers} \hat{\subset} N, \quad \text{life style,} \quad \text{original and natural}]$$

$$—\!\!|\, L = [\text{primitive people}, \quad \text{life style}, \quad \text{original and natural}]$$

Then, according to the divergent analysis of "one-matter, multi-characteristics":

$$L —\!\!|\, L' = \begin{bmatrix} \text{primitive people}, & \text{residence type } c_1, & \text{nest} \\ & \text{residence location } c_2, & \text{on the tree} \\ & \text{means of transportation } c_3, & \text{on foot} \\ & \text{food source } c_4, & \text{natural world} \end{bmatrix}$$

Wherein, the set of objects with same characteristics of "primitive people" is:

$$\{ \text{ villagers} \hat{\subset} N, \quad \text{urban people}, \quad \text{external people}, \quad \text{foreign traveller}, \cdots \}$$

The measure value range of characteristics c_1, c_2, c_3, c_4 are respectively:

$V(c_1)$={nest, wooden house, stone house, building, brick house, cave house, ⋯}

$V(c_2)$={on the tree, on ground, underground}

$V(c_3)$={on foot, ride, take bus, ⋯}

$V(c_4)$={natural world, plant $\wedge$ breed, purchase, ⋯}

Because we want to build a consumer site that can satisfy L_4 and is supplied to urban people, external people or foreign travelers, we should make extension transformation of matter-element L':

$$T_1 L' = \begin{bmatrix} \text{urban people}, & c_1, & \text{nest} \\ & c_2, & \text{on the tree} \\ & c_3, & \text{on foot} \\ & c_4, & \text{natural world} \end{bmatrix} = L_1',$$

$$T_2 L_1' = \begin{bmatrix} \text{urban people}, & c_1, & \text{wooden house} \\ & c_2, & \text{ground} \\ & c_3, & \text{on foot} \\ & c_4, & \text{plant} \wedge \text{breed} \end{bmatrix} = L_2'$$

$$T_3 L_1' = \begin{bmatrix} \text{urban people}, & c_1, & \text{wooden house} \\ & c_2, & \text{on the tree} \\ & c_3, & \text{ride} \\ & c_4, & \text{natural world} \end{bmatrix} = L_3', \quad \cdots\cdots$$

can form several programs $\{ T_i, i=1, 2, \cdots \}$, and we can delete, expand and reduce, resolve and combine these programs to get a batch of planning programs. They all aim to realize "building a site that brings urban or external people to consume in village N".

(7) Evaluation of Ideas

Not all planning programs formed with above extension transformations are feasible and we must evaluate and select. According to the requirement of L_4, i.e. L_4 is considered as a measurement indicator. Select measuring indicator set as:

$$MI=\{MI_1,\quad MI_2,\quad MI_3\}$$

Wherein, MI_1=(feature, unique), MI_2=(development fund, little), MI_3=(real resource required, existing), MI_1 is the condition that must be satisfied. For all planning programs, select with SI_1 first and then evaluate with SI_2 and SI_3. E.g. program

$$L_1^*=\begin{bmatrix}\text{urban people}, & c_1, & \text{wooden house}\\ & c_2, & \text{on the tree}\\ & c_3, & \text{on foot}\\ & c_4, & \text{natural world}\end{bmatrix}$$

i.e. "building wooden house on trees, let urban people walk by, and get food from natural world";

$$L_2^*=\begin{bmatrix}\text{urban people}, & c_1, & \text{wooden house}\\ & c_2, & \text{ground}\\ & c_3, & \text{on foot}\\ & c_4, & \text{plant}\wedge\text{breed}\end{bmatrix}$$

i.e. "building wooden house on ground, let urban people walk by, and get food through planting and breeding";

$$L_3^*=\begin{bmatrix}\text{urban people}, & c_1, & \text{wooden house}\\ & c_2, & \text{on the tree}\\ & c_3, & \text{on foot}\\ & c_4, & \text{purchase}\end{bmatrix}$$

i.e. "building wooden house on trees, let urban people walk by, and get food through purchasing"; …

Because there are many trees in the village and wood materials are existing real resource. Wooden houses are buildings that can be constructed by villagers. If villagers can build wooden house on trees and let urban people walk by, they can fully experience the original life style of human ancestors. Thus this planning meets the condition of "uniqueness". But constructors and constructing materials have been existed, which also meets the conditions of "little development fund" and "utilization of existing resources". For the selection of "means of transformation, development fund must be added if "riding" or "taking vehicle" is selected. And "original and natural" color is lost, thus "walking" is selected. Food source should be determined by the time when travelers stay and hobbies.

From above analysis, we can confirm following planning program:

$$L^*=\begin{bmatrix}\text{external people}, & c_1, & \text{wooden house}\\ & c_2, & \text{on the tree}\\ & c_3, & \text{on foot}\\ & c_4, & \text{natural world}\vee(\text{plant}\wedge\text{breed})\vee\text{purchase}\end{bmatrix}$$

i.e. "building wooden house on trees, let external people walk by, and get food from natural world, or through plant∧breeding, or purchasing".

(8) Generate concrete planning program and select better solution

Match and integrate resources required for realizing planning program to form several planning programs. Then evaluate according to social standard, economic standard, technical standard and feasibility standard to select several programs for decision makers to choose. Only one planning program is listed here without detailed description:

1) Select several trees in the forest of village *N*. Build small wooden house for 2~3 people to live on trees. We can use local material and the villagers can be considered as constructors;

2) Build a parking lot at 5km from the village. To keep the “originality” of the village, travelers must enter the village without driving vehicles;

3) Organize a batch of villagers with “original costume” to popularize in cities, or make “news events” to let news media publicity, report and attract urban people to travel, take a holiday and experience the original life;

4) With the extension of market, more tree houses can be expanded after partial capital is accumulated to attract more domestic and foreign travelers.

(9) Draw up, implement and improve planning program (Omitted)

5.6 Extension Design Method

5.6.1 Research Overview

Extension design refers to the research of contradictory problems in design process with extension theory and methods (including formal representation, modeling, transformation, reasoning, evaluation and decision) so as to find a new design theory and method of priority design program.

The biggest difference between theory and methods of extension design and those of other designs lies in its formalization is combined with qualitative and quantitative. It establishes extension models to avoid the disadvantage of frequent omission of some practical content of problem in mathematical modeling. It also avoids the disadvantages of insufficient formalization and quantification in current existing design methods. It supplements, improves and further develops modern design theory and methods.

The earliest research on extension design dates from the initial stage of Extenics application study. It was first involved in the field of new product conception [2], studied the three creativities of new product conception and was preliminarily applied to product design [9].

Since 1998, Professor Zhao Yanwei from Zhejiang University of Technology started to study the concept design of mechanical products. She made a formal description of the function, principle, layout, shape, structure and other upstream design knowledge with theories and methods in Extenics, and proposed a design method based on multilevel rhombus thinking mode and combined with complex product qualitative and quantitative, which supplied a new approach to the formalization and intellectualization of dialectical thinking of concept design and obtained lots of innovative achievements [29-31]. Professor Yang Guowei from Qingdao University started to study product innovative design with theories and methods in Extenics since 2002 and obtained many achievements [32-34]. Professor Zou Guangtian from the School of Architecture of Harbin Institute of Technology studied the conjugate problems in Extenics and architectural design since 2004 and probed to apply extension planning methods to landscape design [35]. Later, he further studied architectural design innovation and extension thinking mode and developed a systematic research on extension architectural planning and design [36，37].

Extension design methods include product concept design with extension methods (or new product conception) and disposal of contradictory problems in design process. Based on the product innovation in 5.4, this section will introduce three creativities for designing new products. It also introduced the concept generation process of bionic products through cases and then simply introduced the method to resolve contradictory problems in design process as well as the idea of extension design system for dealing with contradictory problems in design process with computers. See other contents in corresponding references.

5.6.2 New Product Conception from Solving Contradictory Problems

In fact, new product conception based on extension methods refers to the concept design of new products. Starting from resolving contradictory problems in essence, it conceives an n-dimension basic-element. With extension methods, we start from the needs of consumers or existing products respectively to conceive a series of new products, especially the products which cannot be thought of with general methods. Three creativities for designing new products in reference ［9］ are all proposed for the need of resolving contradictory problems.

While introducing product innovative method in 5.4 of this book, the thought of three creativities of new product conception was once introduced. This section will offer the concrete steps of the three creativities and illustrate the concept generation process of bionic products with bionic product conception as an example.

1. First creative method

First creative method refers to the method of conceiving new products when consumers have the demand for certain functions which cannot be satisfied by existing objects in objective world. The contradictory problem then is $P=G*\pounds(M)$. Therein, G refers to consumer demands and $\pounds(M)$ refers to the matter-element set of existing products.

Main steps of first creative method are as follows:

(1) Confirm the Characteristics of Product *O* to Be Created

Start from the consumers' demands for product functions first, and then confirm the function characteristic set $\{c_f\}$ of products to be created through analyzing the demand. Function characteristics are confirmed by property characteristics, thus property characteristic set $\{c_g\}$ should be confirmed after confirming function characteristics. However, the property characteristics of objects are confirmed by real-meaning characteristics, thus real-meaning characteristic set $\{c_r\}$ for generating these property characteristics should also be confirmed.

(2) Confirm the Measure Values of Above Characteristics about Product *O* to Be Created

According to the demands for the size of product function, confirm the measure value v_f of every function characteristic c_f. Then calculate the measure value v_g of its property characteristic c_g. Calculate corresponding measure value v_r of real-meaning characteristic c_r based on these values to get the implication system of characteristic-element set of product O to be created:

$$\{(c_f, v_f)\} \Leftarrow \{(c_g, v_g)\} \Leftarrow \{(c_r, v_r)\}$$

(3) Confirm the Hard and Soft Parts of Product *O* to Be Created

According to the real-meaning characteristic-element set $\{(c_r, v_r)\}$, make real-meaning matter-element set $\{(O_r, c_r, v_r)\}$. They can be considered as the matter-elements of spare parts, materials and raw materials etc., thus

$$\mathrm{hr}O = \prod \{O_r\}$$

Then design the relations among spare parts, i.e. soft part $\mathrm{sf}O$ of the product.

(4) Confirm the Latent and Negative Parts of Product *O* to Be Created

Based on the demand for product potential functions, modify the conception with the transformation of matter-elements to make O have the potential functions required. Meanwhile, consider the negative part of O about function value, i.e. the negative part $\mathrm{ng}_c O$ of the product. Modify the conception with matter-elements to reduce product side effect.

From above process we can get numerous conception programs of product O to be created, i.e. the conception matter-element set of product $\{M\}=\{(O,\quad C,\quad V)\}$.

(5) Evaluation

Make overall evaluation of each program in $\{M\}$ to confirm relatively reasonable conception program.

Above steps can be shown with the flow chart in Figure 5.22.

Start from unsatisfied consumers' demands to confirm the functional characteristic-element set $\{(c_f, v_f)\}$ of product O

↓

Get the property characteristic-element set $\{(c_g, v_g)\}$, and $\{(c_g, v_g)\} \Rightarrow \{(c_f, v_f)\}$

↓

Confirm real-meaning characteristic-element set $\{(c_r, v_r)\}$ and $\{(c_r, v_r)\} \Rightarrow \{(c_g, v_g)\}$

↓

Confirm hard part matter-element set $\{(O_r,\quad c_r,\quad v_r)\}$ of O

↓

Confirm soft part sf$O$ of O

↓

Confirm the latent and negative pats of O

↓

Confirm product conception set $\{M\}$

↓

Evaluate and confirm conception program

Figure 5.22 First Creative Method of New Product Conception

2. Second creative method

Second creative method refers to the method of conceiving new products from one or several products through changing some matter-element factors of it (or them). This creative method is the common method to conceive series or composite products.

Main steps of second creative method are as follows:

(1) Resolve the original product

Resolve original product *O* and list their imaginary and real parts, soft and hard parts, latent and apparent part, negative and positive parts. List their mid-part as well when necessary.

(2) List main characteristics of original product *O* and its conjugation part

List main function characteristics, property characteristics and real-meaning characteristics of described product and each conjugate part: $\{c_f\}$, $\{c_g\}$ and $\{c_r\}$.

(3) Calculate corresponding measure value

Calculate corresponding measure values of above characteristics.

(4) List the matter-elements of described product *O* at different levels $M, M_i, M_{ij}, \ldots (i = 1, 2, \ldots, n; j = 1, 2, \ldots, m)$

$$M = \begin{bmatrix} O, & c_1, & v_1 \\ & c_2, & v_2 \\ & \cdots & \cdots \\ & c_n, & v_n \end{bmatrix}, \quad M_i = \begin{bmatrix} O_i, & c_1, & v_{i1} \\ & c_2, & v_{i2} \\ & \cdots & \cdots \\ & c_n, & v_{in} \end{bmatrix},$$

$$M_{ij} = \begin{bmatrix} O_{ij}, & c_1, & v_{ij1} \\ & c_2, & v_{ij2} \\ & \cdots & \cdots \\ & c_n, & v_{ijn} \end{bmatrix}, \quad \ldots\ldots$$

Obviously

$$M = \prod_{i=1}^{n} M_i = \prod_{i=1}^{n} \prod_{j=1}^{m} M_{ij} = \cdots$$

(5) Make matter-element transformation

Make transformations and combinations for each matter-element obtained from step (4) to generate various new functions and functional values and conceive new products. The basic transformation forms are substitution, decomposition, increasing and decreasing, expansion and contraction. Through the basic transformations of related matter-element factors and calculation of transformations, various new product conception programs can be obtained:

$$TM = \prod_{i=1}^{n} T_i M_i = \prod_{i=1}^{n} \prod_{j=1}^{m} T_{ij} M_{ij} = \cdots$$

(6) Preliminary evaluation

Establish evaluation system to evaluate the new products formed after above matter-element transformations. Then select those with higher superiority for the next step.

(7) Design the conjugation part of new products.

(8) Select proper raw materials and spare parts.

(9) Make detailed evaluation and modification to confirm new product conception program.

Above steps can be shown with the flow chart in Figure 5.23.

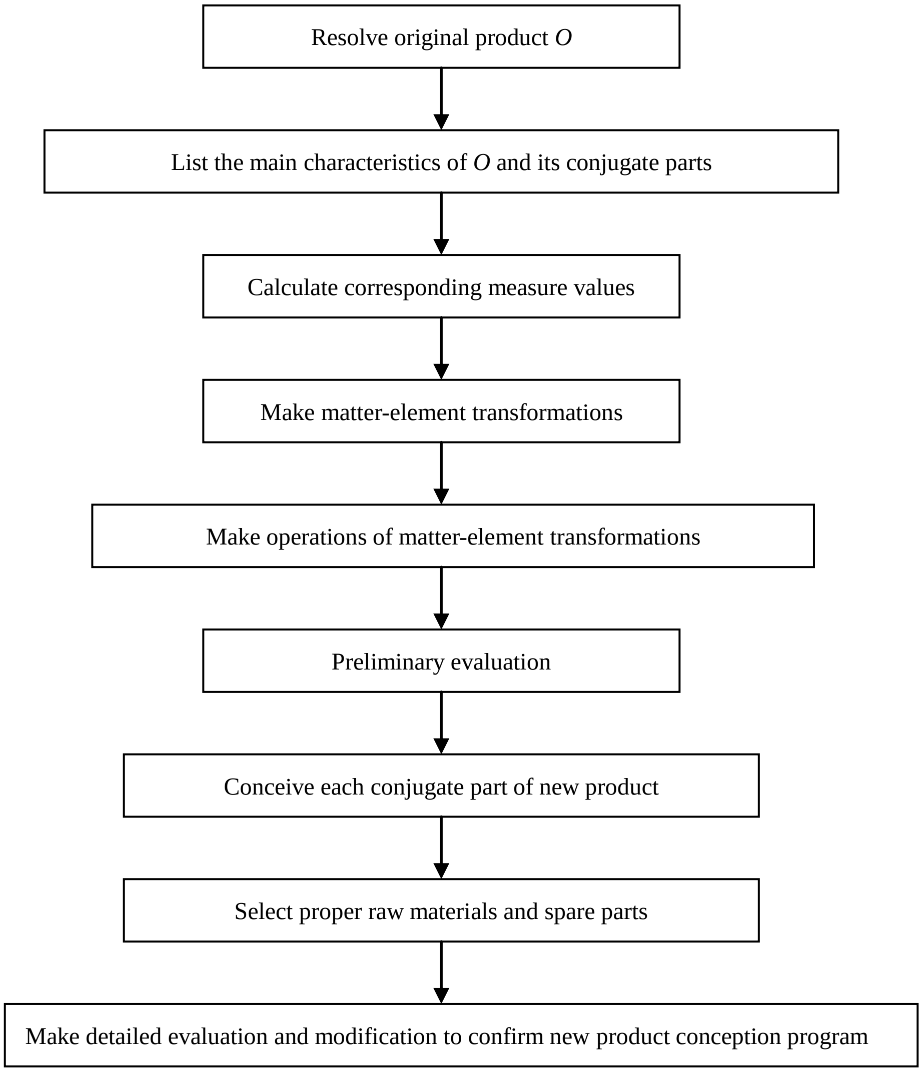


Figure 5.23 Second Creative Method of New Product Conception

3. Third creative method

Third creative method refers to the method of changing the demerits of products to merits through extension transformations or transform operations from the demerits of existing products.

If matter-element M composed of measure values of some characteristics of existing products cannot meet the demand G of certain consumers, or certain consumers feel unsatisfied with some functions of products, contradictory problem $P=G*M$ is formed.

Main steps of third creative method are as follows:

(1) Present existing product O as an n-dimension matter-element

$$M = \begin{bmatrix} M_1^{(1)} \\ M_2^{(1)} \\ \vdots \\ M_n^{(1)} \end{bmatrix}$$

Therein, $M_{0i} = (O, c_{0i}, v_{0i}), i = 1, 2, \cdots, n$.

(2) List consumer complaints or demand G so as to form contradictory problem $P=G*M_0$.

(3) List the function demerits, modeling demerits and value demerits of product with demerit listing method. Find corresponding branch matter-element and arrange the branch matter-elements of n-dimension matter-element M_0 again as

$$M = \begin{bmatrix} M_1 \\ M_2 \\ \vdots \\ M_m \\ \vdots \\ M_n \end{bmatrix}$$

Therein, $M_1, M_2, ..., M_m$ are the branch matter-elements of demerits. $M_i = (O, \quad c_i, \quad v_i), (i = 1, 2, ..., n)$.

(4) Make extensible analyses and extension transformations of the branch matter-elements of demerits $M_i\,(i = 1, 2, ..., m)$, i.e. make $T_i M_i = M_i^*$, $(i = 1, 2, ..., m)$. Record $TM = M^*$ as one n-dimension matter-element without branch matter-elements of demerit.

Numerous M^* can be got from the process above and then a series of new product O^* can be obtained.

(5) Evaluation: establish evaluation system. Make technical evaluation, economic evaluation and social evaluation of above new product O^* so as to select those with higher superiority as the conception program.

Above steps can be shown with the flow chart in Figure 5.24.

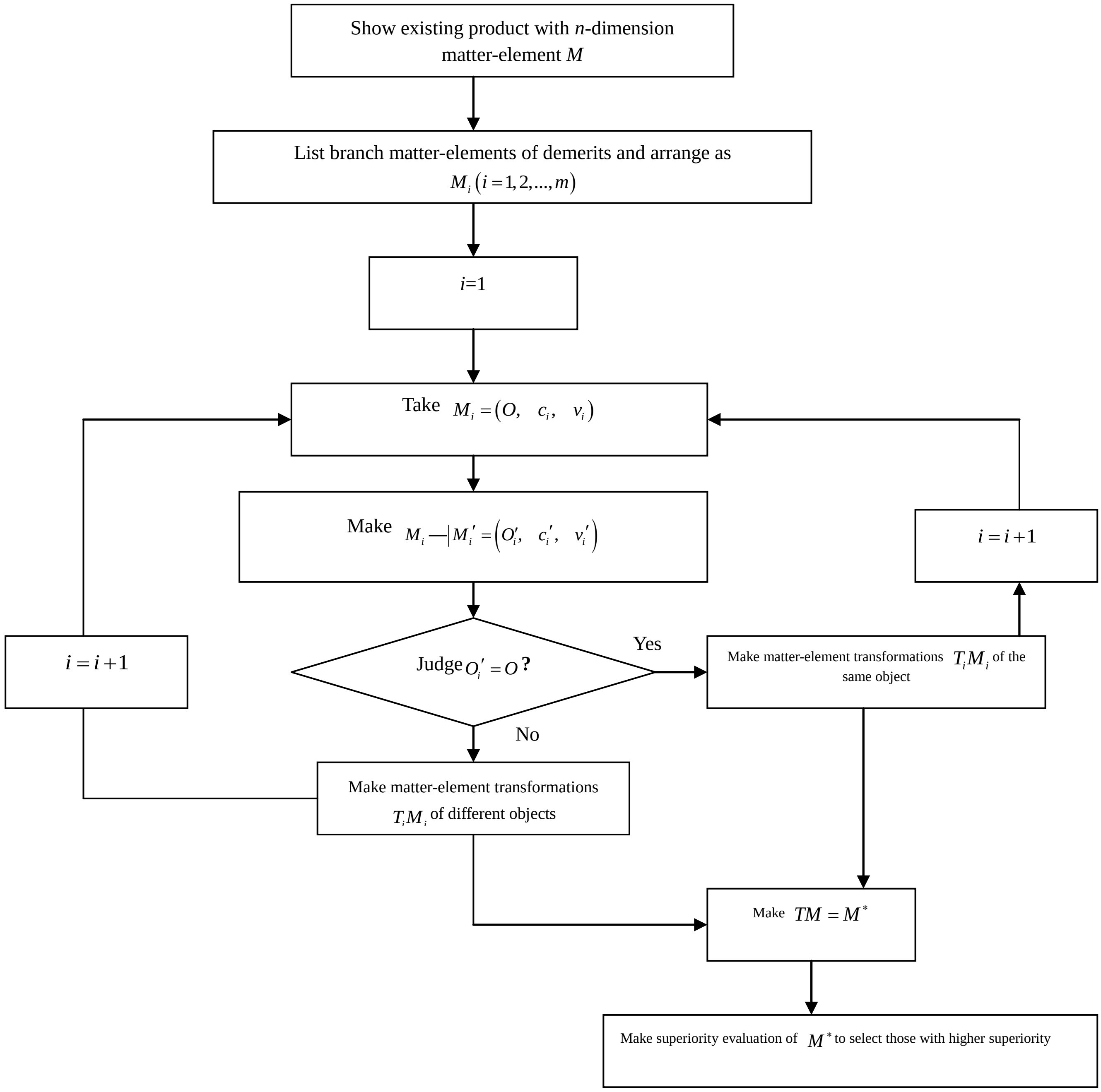


Figure 5.24 Third Creative Method of New Product Conception

While conducting new product conception (or product concept design), we can use one of the above three creativities, or we can use them together. Since product innovation usually aims to resolve contradictory problems, it is unnecessary to establish the extension models of obvious contradictory problems while using above creativities. Thus the function of compatibility degree for measuring contradictory problems needn't be established either. We usually make direct analysis and transformation of consumer demand and existing products to get new product creativity or concept.

4. Concept generation process of bionic products

The Bionics supplies new design idea, operating principle and system constructing method to engineering technology through studying the structure, character, principle, behavior and interaction of biosystem.

In the development history of Bionics, many examples as follows exist: Lu Ban's hands were cut by the grass with teeth while lumbering on the mountain, then he was inspired to invent the saw; someone invented the wheel while seeing fleabane product flying in the air; Volt designed the Voltaic Cell with the electric organ of electric fish as the model; scientific and technical personnel developed the research on antifouling products through modifying the self-purification principle of lotus leaf at the moment of epiphany. To sum up, lots of “bionic concepts” come from numerous smart men’s “sudden inspiration”, “moment of epiphany” and other unusual and wonderful thoughts. Then is there any law for these “bionic concepts”? Can we study a set of methods to propose a series of “bionic concepts” with the assistance of computers according to certain procedures and select the direction for study through evaluation? Meanwhile, help scientists and engineers to make “test optimization design” with computers.

Extenics studies the theories for resolving contradictory problems and probes the methods for generating ideas, tricks and ways. It has also proposed the initial framework of “extension strategy generating system” and designed the experimental software. Combining these achievements and the Bionics can generate lots of “bionic ideas” for resolving corresponding contradictory problems with the merits of “rapid speed and large memory” of computers according to various contradictory problems in the field of engineering technology. “Bionic concepts” for the reference of product innovation personnel can be obtained through evaluations. The program for inventing various new products can also be obtained with the professional knowledge of engineering technology. We name these “bionic concepts” and “product inventive programs” generated by the combination of Bionics and Extenics as “bionic concept generating methods based on Extenics” and “bionic product inventive methods based on Extenics”.

(1) Study the Generation Mechanism of “Bionic Concept” with Extension Models

All kinds of contradictory problems will occur in our social practice and engineering technology. The study of “bionic concepts” aims to find the way to resolve certain contradictory problems in essence. Thus extension methods can be adopted to study the generating mechanism of “bionic concept” through summarizing the practice of resolving contradictory problems in the development process of Bionics. It can be said that “extension strategies” finally obtained through establishing extension models of contradictory problems and deducing the resolving process with extension methods are just “bionic concepts”. Following contents need to be studied:

1) Study how to establish the extension models of contradictory problems in engineering technology and biological treatment, especially describing biological functions with basic-elements.

2) Study the congruent relation between the goal and condition of contradictory problems in engineering technology and biological treatment. Describe the congruent relation between them with basic-element from qualitative and quantitative perspectives.

3) Study the resolving process of transforming contradictory problems in engineering technology to biological contradictory problems, and reverse transforming contradictory problems of biological treatment to those in engineering technology.

4) Form basic theories and methods for generating bionic concepts.

Now take the invention of anti-adhesive bionic plow and bionic electric cooker of Bionics scholars as examples to simply discuss the generating mechanism of bionic ideas.

[Example 5.4] In countryside, much clay is usually adhered while tilling cohesive land with plow, which is very inconvenient to operate with low efficiency. Now let’s resolve this contradictory problem with extension methods. Set the goal basic-element of this problem as

$$G=\left[\text{Prevent},\quad \text{dominating object},\quad \begin{bmatrix}\text{Adhere}, & \text{dominating object}, & \text{soil} \\ & \text{acting object}, & \text{plow}\end{bmatrix}\right]$$

And the condition basic-element formed by existing plow is:

$$L=\left[\text{Surface}\,\hat{\subset}\,\text{plow},\quad \text{smoothness},\quad \text{smooth}\right]$$

Therein, "$\text{Surface}\,\hat{\subset}\,\text{plow}$" refers to the surface of plow.

Make divergent analysis of *G* first to get

$$G_i=\left[\text{Prevent},\quad \text{dominating object},\quad \begin{bmatrix}\text{Adhere}, & \text{dominating object}, & \text{soil}\vee\text{excrement} \\ & \text{acting object}, & \text{biological } v_i\end{bmatrix}\right]$$

Therein, $v_i \in V=\{v_1,\ v_2,\ \ldots . v_n\}=\{\textit{Earthworm, mantis,pangolin,....}\}$.

Through surveying and analyzing the common characteristics of structure $v_i\,(i=1,2,\cdots,n)$ with biological knowledge we can get:

$$L_i=\left[\text{Skin}\,\hat{\subset}\,v_i,\quad \text{smoothness},\quad \text{coarse}\right],(i=1,2,...,n)$$

Form knowledge through investigation: $L_i \Rightarrow G_i,(i=1,2,...,n)$. Make a transformation with the knowledge: $T_1L=L'$, therein

$$L'=\left[\text{Surface}\,\hat{\subset}\,\text{plow},\quad \text{smoothness},\quad \text{coarse}\right]$$

T_1 refers to "bionic idea"—change smooth plow surface to coarse surface to realize the goal.

Scholars of Bionics made the tests based on this idea to prove its feasibility. Then they invented "bionic plow" with professional knowledge.

For bionic plow, there is

$$L''=\left[\text{Surface}\,\hat{\subset}\,\text{bionicplow},\quad \text{smoothness},\quad \text{coarse}\right]$$

Practice shows: $L''\Rightarrow G''$, therein

$$G''=\left[\text{P revent},\quad \text{dominating object},\quad \begin{bmatrix}\text{Adhere}, & \text{dominating object}, & \text{soil} \\ & \text{acting object}, & \text{bionic plow}\end{bmatrix}\right]$$

Make transformation: $T_2L''=L_{0i}$, therein

$$L_0=\left[\text{Contact surface}\,\hat{\subset}\,v_0,\quad \text{smoothness},\quad \text{coarse}\right],v_0\in\{\text{mining car, mud truck,}\ldots\ldots\}$$

T_2 refers to the bionic idea developed for many times, i.e. make the contact surface of mining car, mud truck and other mechanical, loading and unloading devices coarse to resolve their contradictory problems of adhesive soil.

Later, scholars of Bionics expanded the value range of v_0 to an electric cooker and generated new bionic idea: $T_3L_0=L_0'$

$$L_0' = \left[\text{Contact surface} \,\hat{\subset}\, \text{electric-cooker}, \quad \text{smoothness}, \quad \text{coarse} \right]$$

Based on tests, they researched "bionic electric cooker", i.e. make "smooth electric cooker liner and food to "coarse" to resolve the contradictory problem of adhesion of rice.

All these are the results of bionic scholars through repeated applications of bionic technology.

(2) Develop Bionic Concept Generating System with Extension Methods and Computer Technology

To research the "bionic concept generating system based on Extenics" based on above analysis of bionic concept generating mechanism through combining existing achievements in Biology, Engineering, Bionics and Computer Science together according to basic theories and methods of extension strategy generating system has essential value to the development of Bionics.

Basic steps are as follows:

1) Establish basic base, including biological function base, artificiality function base and conjugation part basic-element base.

2) Establish extensible basic-element base and extensible knowledge base with extensible analytical methods.

Expand extensible basic-element base and extensible knowledge base with the divergent tree, correlative net, decomposition/combination chain and implication system in extension methods according to the goal of contradictory problem.

3) Analyze the biological structure with conjugation analytical method to establish biological knowledge base.

In Extenics, besides the systematic analysis of object structure from the system science, there are researches of materiality, dynamics and contrariety as well, which are correspondingly classified as soft and hard parts, imaginary and real parts, latent and apparent parts, negative and positive parts.

Among living things, biological structure can also be analyzed from above conjugative characteristics. The very characteristics of these structures make the living things have various functions. We need to study the real-meaning characteristics and functional characteristics of each conjugation part of living things from qualitative and quantitative perspectives, establish corresponding knowledge base and expand "extensible knowledge base' with extension methods.

4) Study the transformation rules suitable for the Bionics to establish bionic transformation rule base.

Extension transformation is the basic tool for resolving contradictory problems in Extenics. There are three existing types of extension transformation rules: a) basic transformation rule; b) transformation operating rule; c) conductive transformation rule. See also 2.4 of this book.

Change these transformation rules to bionic transformation rules adjustable to the Bionics, and establish corresponding bionic transformation rule base.

5) Generate "bionic ideas" and the rules of elimination through extension transformations.

According to the goal basic-element, the application of transformation rules to extensible base can generate a batch of "ideas". Some of the ideas are valuable while some are infeasible. We must study the "rule of elimination" to eliminate invaluable "ideas". The left ideas enter the "ideas base". Different goals have distinct "ideas which can be storage according to types.

6) Make detailed evaluation of the "ideas" with superiority evaluation method to confirm "bionic concept" which

can conduct tests.

Generate the block diagram of the system based on bionic concepts in Extenics as shown in Figure 5.25.

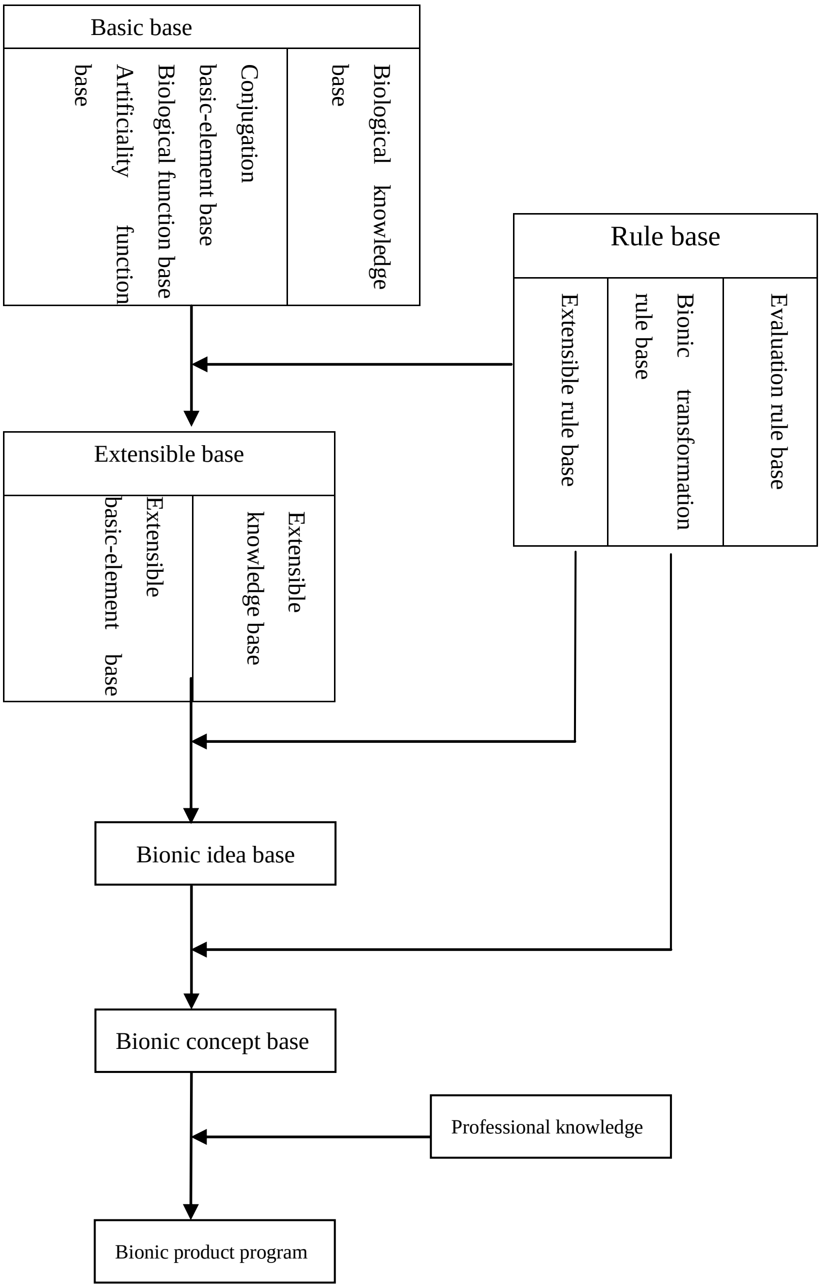


Figure 5.25 Bionic Concept Generating System Based on Extension Methods

(3) Develop the Auxiliary Software for Inventing Bionic Products Based on Extension Methods with Professional Knowledge

Propose “bionic concepts” for different contradictory problems. Make quantitative and qualitative analysis of materials, form and structure with knowledge in corresponding fields based on extension methods. Assist the Engineering Technology Department to develop “bionic concept” to new product development programs with computers. Or develop “bionic concept” generating system with repeated development with extension methods and based on existing bionic products. The bionic product concept generating system based on extension methods can be applied to lots of fields as shown in Figure 5.26.

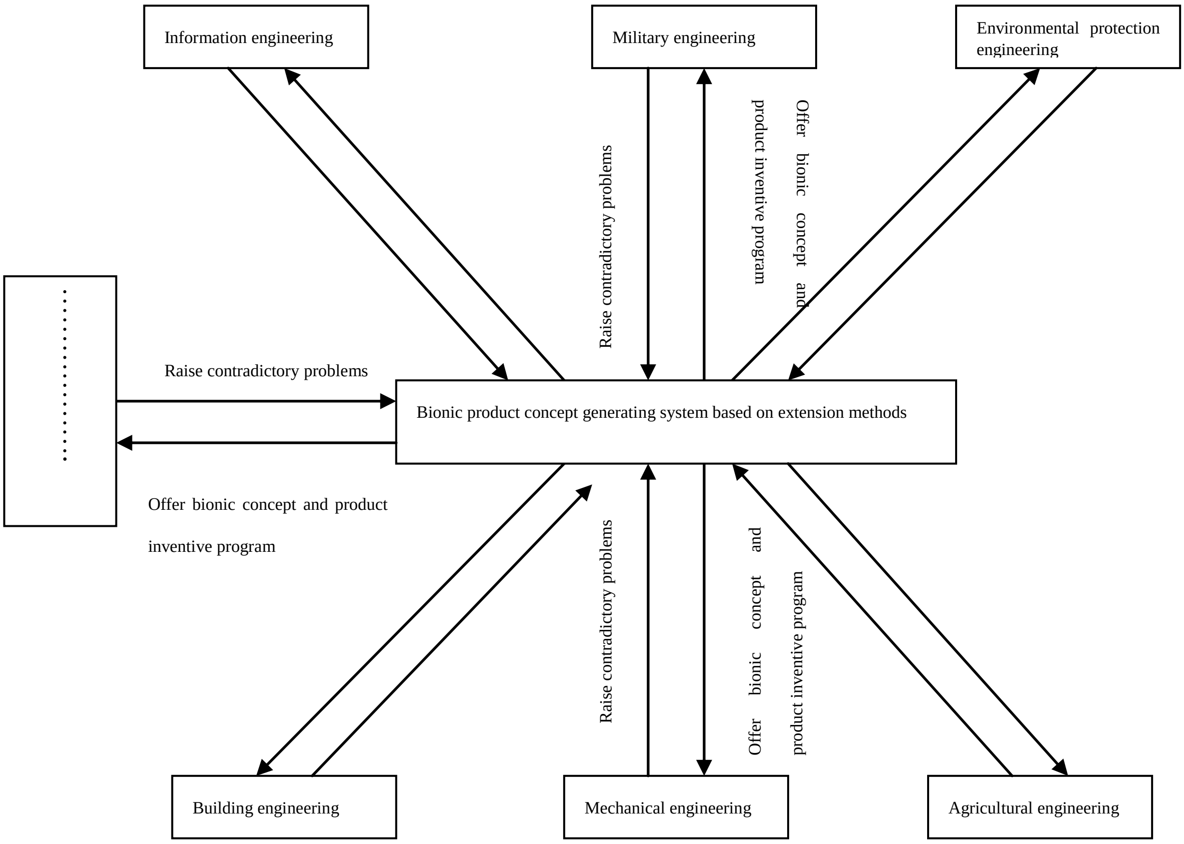


Figure 5.26 Applications of Bionic Product Concept Generating System Based on Extension Methods

5.6.3 Solve the Contradictory Problems in Design Process

In design process, the designer will meet various contradictory problems, e.g. contradictory problems of needs and function, those among functions, those between function and structure, those between function and cost and those among subsystems etc. Resolving these contradictory problems with extension methods is also one core content of extension design method.

Reference [38] studied the solution of contradictory problem of space form in building indoor space design with extension methods. Thus space problem is not only the design difficulty and core of architect but also the focus of building users in building indoor design. The disposal of space problem reflects the technical level of architects. Meanwhile, it can directly inspect whether comfortable living conditions are offered to people. Space problem involves in the characteristic problem of shape. These characteristics include the mathematic characteristics of abstract geometry and the original characteristics of shape. Thus space contradictory problem involves in both the "shape" and "quality" contradictions of function needs and space. We can study the solutions of various contradictory problems in building indoor space design with the basic-element theory and extension set theory proposed in Extenics and with extensible analysis and extension transformation as main analytical and transformation methods. Besides, the consistency degree of space function and human behavioral requirements is the core content in building space design. It is also an important evaluation standard to assess space quality. Behavioral requirements include practical behavioral requirement (apparent behavioral requirement) and future behavioral requirement (latent behavioral requirement). Contradictory problems in building indoor space design include: contradictory problems between space function and practical behavioral requirement and those between space function and future behavioral requirement etc.

Lots of contradictory problems exist in mechanical design, road and bridge design and ordnance design. All these contradictory problems can be resolved with the idea and method of extension design. Interested readers can conduct intensive research.

Contradictory problems in design process can also be classified into two kinds as common contradictory problems, including incompatible problem and opposite problems. In Extenics, the way to resolve incompatible problems with computers is the extension strategy generating method. The way to deal with opposite problems is the transforming bridge method. In design, professionally accumulated basic database can be adopted to propose the superiority strategy for resolving existing contradictory problems through the extension strategy generating method and the transforming bridge method.

Current widely used AutoCAD, 3D Max, PHOTOSHOP and other computer auxiliary building design software are the tools for helping people to make building mapping, modeling, rendering and effect processing. However, they are not the expansion and extension of human brain capacity in the true sense. Thus they cannot make the design with artificial intelligence factors, or analyze and evaluate design program through imitating the designer. Since black-box property exists in the design thinking process of the designer, the thought and design process of the design are always difficult to imitate with computers to make design concept with artificial intelligence property although computers have been used to make relevant data processing and imitation in design research. Computer aided design cannot achieve real major breakthrough and the main difficulty lies in the designer’s design thinking process, wonderful idea and excellent conception are hard to be formalized and intelligentized.

The formalized expression of various conditions, contradictory problems and non-contradictory problems, various relations involved in the design through Extenics can make formalized deduction of the design thinking process, help the designer select the direction of design innovative thinking and form creative design. The combination of principles and methods in Extenics with Design and Computer Science can push forward the contradictory problems occurred in computer aided design and aided processing design process through the merits of formalized models in Extenics. This aspect is being studied now. We believe the design system based on the disposal of contradictory problems will come out soon.

5.7 Brief Introduction to Extension Control and Extension Detection Methods

5.7.1 Extension Control Method

1. Research overview

The method of applying extension theory and methods in a control field to deal with contradictory problems in control is called the extension control method. It offers a way that is worth exploring to resolve contradictory problems in a control field.

In 1994, Professor Wang Xingyu from East China University of Science and Technology published "On Extension Control" [39] in the *Control Theory and Application*. He first proposed the concept, definition and framework of extension control. Then he further studied extension control and its intelligent meaning and published several related papers [40-41]. In 1996, Pan Dong and Jin Yihui etc. from Tsinghua University published "Exploration and Research of Extension Control" [42] in the *Control Theory and Application*. They proposed two-layer extension controller and made a pilot study on the extension field of extension control. Later, lots of scholars further published several papers [43-46] about extension control in succession. Besides some scholars from Mainland China explored the extension control, scholars from Taiwan studied it as well. In 2001, Zhang Weiting and Yang Zhixu from Tamkang University published "Design of Extension Controller in Mobile Crane Overload Prevention System" in *China Artificial Intelligence Progress* and resolved the proper adjustment of mobile crane when dangers occur at work so as to avoid the accidence caused by overload. Shi kaizhen from Tamkang University published "Application of Extension Control in Automatic Vibration Attenuation of Component Inserter" and resolved the vibration abatement of component inserter at work, which makes the machine operate in steady, stable and efficient state. Taiwan scholars Chen Zhenyuan and Weng Qingchang etc. published "Design of Self-Adapted Extension Controller in Nonlinear System" [47] and "Design of Extension Controller Based on Sliding Model Control" [48] in *China Engineering Science*, which offers two different methods for the practical design of extension control.

Extension control also draws the attention of some international control scholars. At ICITA Conference, this control mode attracts the great interest of participant scholars of many countries.

This section only introduces the difference between extension control idea and traditional control. Interested readers can see corresponding literatures for reference.

2. Difference between extension control and traditional control

The biggest difference between extension control and traditional control lies in: traditional control resolves the control quality problem of the system. Extension control resolves the control universe of discourse of the system i.e. resolves a pair of contradictory problems of uncontrollable and required to be controlled, which changes uncontrollable to controllable.

Extension control aims at making related control systems in various current fields realize controllability in originally uncontrollable fields through the processing of extension transformations, improving the level of control system from control range, control depth and width, developing larger control potential and having more obvious improvement in product quality, level, energy saving, material saving and many other aspects. It has important significance to the application of information control and power system as well as economic growth.

Extension control focus on the state dependent degree of Extenics and studies control problems from the perspective of information transformation. It processes the fields which are considered as uncontrollable by traditional control method and change them to controllable under certain conditions, which changes uncontrollable state in a control system to controllable state and improves the capacity and level of control system. Researchers on extension control try to establish a new control method to make up the insufficient of traditional control while processing contradictory problems and develop traditional control theory.

The control range of control system with several fields is under certain restrictions. The operating state is uncontrollable if limited range is exceeded, which may even cause dangerous accidents. Changing the uncontrollable state of the system to controllable not only expands the operating range of control system. What's more, it prevents dangerous accidence and improves production security. The expansion of potential of control system is beneficial to reduce equipment investment and save capital, energies and materials.

Internationally, modern control theory, fuzzy control theory and neural network control theory are combined with various advanced optimization theories and raise various control methods which integrate multiple technologies, realizing the intelligent control of the system at different degrees. However, all other existing control methods aim to improve the control quality of the system. Rapidity, steadiness and reliability are major factors to measure system control level. All existing control methods are carried out around these factors. Extension control aims to extend the control universe of discourse of the system and expand its control range, which makes the system have larger control capacity and work on improving control security and reliability.

To change uncontrollable state to controllable state in certain range is a kind of capacity expansion for control systems. It further enhances the control capacity and range of control systems and improves the performance and property of controlled object, which is beneficial to potential development, energy saving and depth use of resources.

Extension controller is the core of extension control system. To better study and design extension control systems, we must start from the design of extension controller.

In later 1990s, domestic scholars proposed and designed extension controller first to study the division of property pattern, dependent degree calculation and realization. They also gradually improved the structure of extension controller, further raised the concepts of upper extension controller and basic extension controller, discussed the structure of upper extension controller, improved the control algorithm of basic extension controller and obtained experimental verification. With the thorough research of extension theories since 2000, basic-element is introduced to extension control and basic-element models of extension control are raised. Aiming at the limitation that self-adapted design only can deal with gradually and quantitatively changed problems, the discussion of applying extension control to make up self-adapted control, establishment of extension self-adapted congestion control methods, processing and control of non-gradually or qualitatively changed dynamic system and unforeseen emergencies with extension control variables and solution of contradictory problems in a control system have become the development direction of current research of extension control technology.

To sum up, extension control aims to make control system change from uncontrollable state to controllable state under certain conditions, resolve the contradiction between uncontrollable and required to be controlled in a control system, extend and improve the control capacity and range of control system. It will play an important role in the system control of industry, agriculture, aviation, traffic, transportation, automobile, machining, boats, appliances, national defense and military affairs.

5.7.2 Extension Detection Method

1. Research overview

Based on extension theory, extension detection establishes a kind of detection theory and method based on extension models through extension transformations, realizing effective detection of physical quantities which cannot be detected, or difficult to be detected with traditional methods.

Among various current power systems, the information in some systems cannot be detected. It mainly depends on that the sensor of corresponding physical quantity doesn't exist, or corresponding sensor cannot be adopted in this environment. However, some systems cannot be detected in certain ranges. These problems directly obstruct the development of production technology.

In bio-medical engineering, various problems about the detection of human visceral organs still exist. Although computed tomography can detect the section of human organs, ultrasonic wave can make certain external detection of some organs, X-ray can make morphology detection of lung and skeleton, unclear pictures and difficult distinction of organ function still exist. In particular, the detection of heart, liver and kidney, early forecast of cancer, ovarian cancer and womb cancer, and forecast of apoplexy still cannot be resolved well. All these are directly related to detection theory, technology, method and means.

In industry, especially in chemical industry, real-time quality detection of final products usually cannot be made. However, the production process is real-time and continuous. Thus unsuccessful real-time detection occurs inevitably, which makes the control of quality become quite difficult. Among appliances which are frequently used in daily life, many physical quantities haven't been detected. For instance, the detection of objects in refrigerator and microwave oven as well as quality and weight of clothes in washing machine hasn't been resolved yet, which will directly influence the intelligent functions of appliances.

Information detection is one of the leading research subjects in information science, which is widely used in many fields. Information detection is based on information measurability while information measurability directly depends on sensors. The improvement of accuracy of single sensor has been quite difficult, yet the mistaken report and ineffectiveness of sensor will also cause system failure. Therefore, data integration is proposed to make information detection with several but not so accurate independent sensors and obtain reliable or more accurate information through the integration of information data. It is also a hot topic in detection technology research for over 10 years.

The research of multi-sensor data integration has a history of more than 10 years. Its research methods can be generally divided into probability statistics and artificial intelligence. The object of research of multi-sensor data integration is just the uncertain information existed in detection. Integration processing can reduce the uncertainty of information and improve the accuracy of object description. Although multi-sensor data integration makes great progress in detection reliability and accuracy, it still cannot resolve all problems. Soft measurement was first proposed by B. Joseph and C. Brosilow in the paper of "Inferential Control of Processes" published in AICHE in 1978. For soft measurement technology, foreign researches and applications are basically limited to the real-time measurement of process control. As a technology facing practical process, many places still need to be improved and studied to reach truly practical application degree. In particular, system theory hasn't been formed at present for soft measurement technology. The method and framework for forming this kind of system theory are insufficient as well. Multi-sensor integration can improve detection accuracy to some degree, but it cannot realize the detection of undetectable physical quantities. Yet soft measurement hasn't offered a set of theory and technology to realize the detection of undetectable physical quantities.

In 1997, Professor Yu Yongquan from Guangdong University of Technology proposed the basic concepts and ideas of extension detection according to the problem that some physical quantities cannot be detected or difficult to be detected in a control system through combining the properties of extension theory. Later, he carried out the research of extension detection technology and method, established the basic framework of this method and published several related papers. See the research results about extension detection in references [49-54].

2. Differences between extension detection and traditional detection

Extension detection aims to make effective detection of undetectable physical quantities in some fields so as to resolve the contradiction between information undetectable and emergent detection. It is very important to the needs of information application in various industries and has important significance to information mining, information control, information processing, information disposal, information conversion and information conductive etc. Extension detection establishes new detection theories based on Extenics to resolve the problem of information undetectable or difficult to be detected in related fields. It provides a detection method different from traditional detection for information science and supplies an effective detection technology to industry, agriculture and economic development, which will have significant scientific meanings and practical values.

Extension detection is different from traditional detection in ideas and technical route. Based on the concepts and theories in Extenics, it adopts new ideas of solving contradictory problems in Extenics to resolve undetectable problems. The basic idea of extension detection is based on the concept of matter-element and divides matter-elements into detectable matter-elements and undetectable matter-elements. If the characteristic measure value of one object can be detected with existing sensors, it will be regarded as detectable matter-element. Otherwise, it is undetectable. In practical detection system, both detectable and undetectable matter-elements exist for the same object. Extension detection just makes use of the detectable matter-element of object, as well as the correlativity between detectable and undetectable matter-elements to get undetectable matter-elements through extension transformation and resolve the detection of undetectable matter-elements.

At present, information detectable directly depends on the sensor and environmental condition. The integration process of models is influenced by data property, reasoning model and constraint conditions. No ideal results have been obtained for the stableness of accuracy. It directly causes information undetectable, i.e. there is no corresponding sensor, or the sensor cannot be applied in certain environment. These two problems are difficult to be resolved with traditional method. The purpose of extension detection research is to realize the normal detection of undetectable information and improve the accuracy of information detection.

5.8 Applications of Extension Methods in Identification, Search and Diagnosis

Identification refers to make sure whether one object belongs to certain kind of objects or something. Search refers to find the object with certain characteristics. During the search, lots of objects conforming to the requirement will usually be found. Then we need to identify which are real and which are inaccurate. Diagnosis refers to make sure the position and what type of something (fault or disease). Both similarities and differences exist among identification, search and diagnosis. Extension methods are mainly applied to two aspects in these three fields:

(1) Identification, search or diagnosis under transformations;

(2) How to change unidentifiable to identifiable, unsearchable to searchable, undiagnosable to diagnosable through transformations.

5.8.1 Application of Extension Methods in Identification

Identification is a rather complicated job. It involves in existing information, applies accumulated knowledge and considers what transformations to use so as to get more information to help the completion of identification. Therefore, the merits of computers like large memory and rapid speed must be used to help people make the identification. Extension identification method is introduced in3.4. The assumption for applying this method is given below.

1. Establishment of basic base

To identify an object, we must use existing information and knowledge. Therefore, basic-element information base, rule base, knowledge base and extension transformation base must be established.

Basic-element information base includes basic information base and extensible information base. Present the problems to be identified with basic-elements and storage them in the base, including the information of goal object, information of existing conditions and information related to them. Based on basic information base, storage the information obtained through extensible rules in extensible information base.

Rule base includes extensible rules, extension transformation rules, evaluation rules and matching rules etc. Extension rules include correlation rules, implication rules, opening-up rules and divergent rules; evaluation rules include dependent function computation rules, superiority evaluation rules and sort rules; matching rules include authenticity computation rules and comparison rule etc.

Basic knowledge base presents related knowledge (e.g. accumulated knowledge and common sense of investigators) with basic-element extensible forms and then storing them in the base. Since the knowledge is represented with basic-element relation forms, people’s common sense and professional knowledge are very easy to be storage in knowledge base, which are also very easy to be extracted and used through related rules.

Extension transformation base includes basic transformation rules, transformation operational rules and conductive transformation rules etc. The cases of obtaining information and resolving problems through transformations are stored in basic knowledge base after being abstracted as expanding formula.

2. Present key basic-element B_{*0i} of class A and corresponding key basic-element B_{0i} of object *O*

Present all key basic-elements or special basic-elements with B_{*0i} and B_{0i}. Suppose their degrees of identification as $\beta < 0$, i.e. cannot identify with conventional identification methods.

3. Make extensible analysis

According to extensible rules, above basic-elements can be expanded as B_{*i} and B_i:

$$B_{*i} = \begin{bmatrix} u_{*i}, & c_{*i1}, & v_{*i1} \\ & c_{*i2}, & v_{*i2} \\ & \vdots & \vdots \\ & c_{*in_i}, & v_{*in_i} \end{bmatrix}, \quad v_{*i} \in V_{*i}$$

$$B_i = \begin{bmatrix} O_i, & c_{i1}, & c_{i1}(O_i) \\ & c_{i2}, & c_{i2}(O_i) \\ & \vdots & \vdots \\ & c_{in_i}, & c_{in_i}(O_i) \end{bmatrix} = \begin{bmatrix} O_i, & c_{i1}, & v_{i1} \\ & c_{i2}, & v_{i2} \\ & \vdots & \vdots \\ & c_{in_i}, & v_{in_i} \end{bmatrix}, \quad (i = 1, 2, \ldots, m)$$

4. Establish dependent functions

Establish dependent function $k_i(x_i)$ and corresponding basic-element extension set $\tilde{E}_{*i}$. Calculate the relativity degree $k_{B_{*i}}(B_i)$ of B_i and B_{*i}, and then calculate the relativity degree of O about A, $k = \underset{1=1}{\overset{n}{\wedge}} k_{B_{*i}}(B_i)$.

5. Make extension transformation

Make transformation T_i to obtain basic-element $T_i B_i = B_i'$ after the transformation:

$$T_i B_i = B_i' = \begin{bmatrix} O_i', & c_{i1}, & v_{i1}' \\ & c_{i2}, & v_{i2}' \\ & \vdots & \vdots \\ & c_{in_i}, & v_{in_i}' \end{bmatrix}$$

Calculate the relativity degree $k_{B_{*i}}(B_i')$ **of** B_i' about B_{*i}, $(i = 1, 2, \cdots, m)$

6. Judge information authenticity

From the characteristics of basic-element knowledge representation methods we know that current knowledge representations can be transformed to basic-elements and various relations for representation. Therefore, while judging the authenticity of some information with common sense and professional knowledge, we can operate with the help of basic-element forms in order to resolve identification problems with computers. Now illustrate the possibility of operation with computers with the simplest examples.

For basic-element *B*, present the authenticity of *B* with number $\alpha(B)$.

(1) Judge the Authenticity with Common Sense Knowledge or Professional Knowledge

From reference [6] we know that all knowledge represented with production rules can be presented with basic-elements. The authenticity of information can be judged with their rules as follows:

1) $(B_1 \Rightarrow B_2) \wedge (B_2 \Rightarrow B_3) \models (B_1 \Rightarrow B_3)$;

2) $(B_1 \Rightarrow B_2) \models (\bar{B}_2 \Rightarrow \bar{B}_1)$;

3) $(B_1 \Rightarrow B_2) \wedge (B_2 \Rightarrow B_3) \models (\overline{B_3} \Rightarrow \overline{B_1})$.

[Example 5.5] In one case, A supplied his information lost in *O* at the moment of t_0. The investigator judged information offered by A was false after analyzing A's sole and looking up the meteorological information that day as heavy rain. The judging process can be made through following common sense with above rules.

Existing common sense: $B_1 \Rightarrow B_2$ and $B_2 \Rightarrow B_3$, wherein

$$B_1 = \begin{bmatrix} \text{Rain,} & \text{control object,} & \text{fall} \\ & \text{position,} & O \\ & \text{time,} & t_0 \end{bmatrix}, \quad B_2 = \begin{bmatrix} \text{Ground,} & \text{state,} & \text{moist} \\ & \text{position,} & O \\ & \text{time,} & t_0 \end{bmatrix},$$

$$B_3 = \begin{bmatrix} \text{Sole,} & \text{state,} & \text{moist} \\ & \text{position,} & O \\ & \text{time,} & t_0 \end{bmatrix},$$

From above rules and meteorological information we know B_2 is true, then

$$\bar{B}_3 = \begin{bmatrix} \text{Sole,} & \text{state,} & \text{dry} \\ & \text{position,} & O \\ & \text{time,} & t_0 \end{bmatrix}$$

must be false, i.e. we could judge whether the person went to *O* at the moment of t_0 through his sole while returning home by way of *O*.

(2) Judge Information Authenticity with Inverse Transformation of Extension Transformation

During the identification, we should rely on lots of collected information. Some information can change "true" to "false", "belong to" to "not belong to" while some information is opposite. Thus the judgment of information authenticity is the first problem to be resolved during identification. For instance, in one case, the face of the death was B, about which the investigator doubted. Later, it was found the skin similar to the characteristic of B was pasted to the face of another person. Then the inverse transformation of extension transformation can be used to confirm the authenticity of information, i.e. uncover the pasted skin to judge the basic-element for describing the face of the death (dead body *A*, characteristic, B) as false information.

3) Judge Information Authenticity with Conjugate Analysis

Judge whether one individual is known individual, i.e. judge whether O_1 is O_0. We can judge from the different conjugate part of O_1. The readers can study on their own.

7. Calculate the Degree of Identification

According to the computation method of identification degree in extension identification methods in3.4.3 and based on the relativity degree and authenticity obtained after above transformations, calculate the identification degrees of basic-element B_i' about B_{*i} after transformations:

$$\beta_{B_{*i}}\left(B_i'\right)=\alpha\left(B_i'\right)\bullet k_{B_{*i}}\left(B_i'\right), \quad \beta\left(T\right)=\mathop{\wedge}_{i=1}^{m}\beta_{B_{*i}}\left(B_i'\right)$$

8. Judgment

The judgment of extension identification methods can be classified into three types: one is judging whether O belongs to A, the second is judging whether O is O_* and the third is judging whether O belongs to one of certain types $A_i\left(i=1,2,\cdots,n\right)$.

(1) Judge Whether O Belongs to A

Judge which field of extension set $\tilde{E}_{*i_0}$ the key basic-element B_{i_0}' with an identification of $\beta\left(T\right)$ after transformation belongs to. If B_{i_0}' belongs to positive extension field, i.e. meet $\beta<0$, $\beta\left(T\right)>0$, thus is means that B_{i_0} is changed from "not belong to B_{*i}" (unidentifiable) to "belong to B_{*i}" after transformation T. Accordingly, O is changed from unidentifiable to "belong to A".

The judging process is shown in Figure 5.27.

(2) Judge Whether O is O_*

For lots of practical problems, we need to judge whether a certain object O is O_*. For instance, whether A who lives in a certain hotel is dressed up by murderer B. The method similar to above can be used to establish B's special basic-element and A's corresponding special basic-element. Repeat above process to judge whether A is B.

The process of judging whether O is O_* is similar to Figure 5.27. And the difference lies in changing the "key basic-element" in this figure to "special basic-element" and changing the conclusion as $O_*\left(t_0\right)=O\left(t_0\right)$ or $O_*\left(t_0\right)\neq O\left(t_0\right)$.

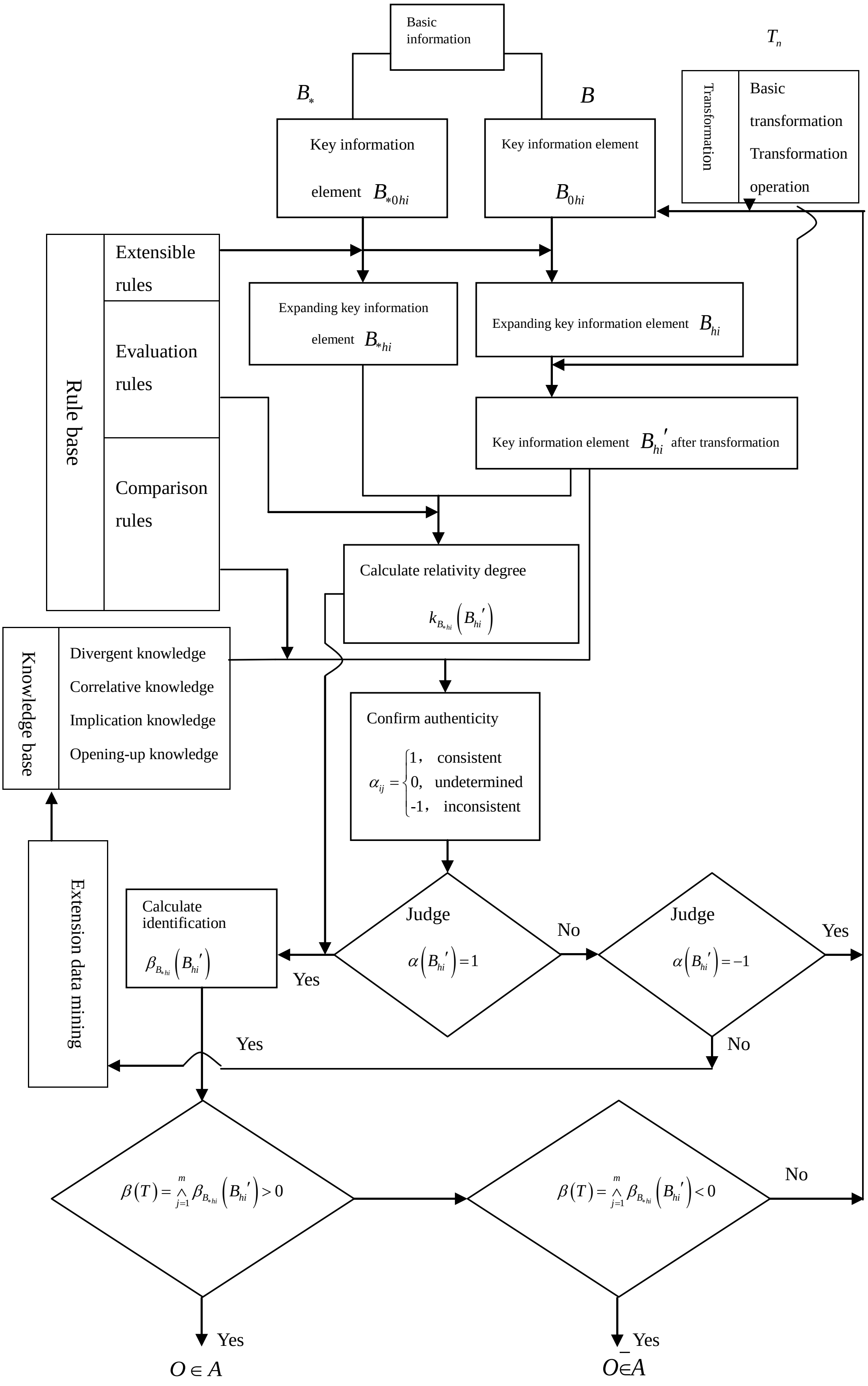


Figure 5.27 Extension Identification Auxiliary System for Identifying Object Type with Key Basic-element

(3) Judge Individual Belong to What Type

Given O and $\{A_1, A_2, ...A_n\}$, judge which type of O belongs to A_i $(i=1,2,...,n)$. The degree of $O \in A_i$ can be calculated as $\beta_i(T)=\beta_i$ with (1). If $\beta_{i_0}(T)=\max\limits_{1\le i\le n}\beta_i(T)$, $O \in A_{i_0}$.

[Example 5.6] In one case, the match degree of face A of dead body *A* is 100, but arsenic is found in the mouth. According to professional knowledge, the complexion after taking arsenic should be swart. Therefore, the flow in Figure 5.28 can be used to judge whether the dead body is A's corpse.

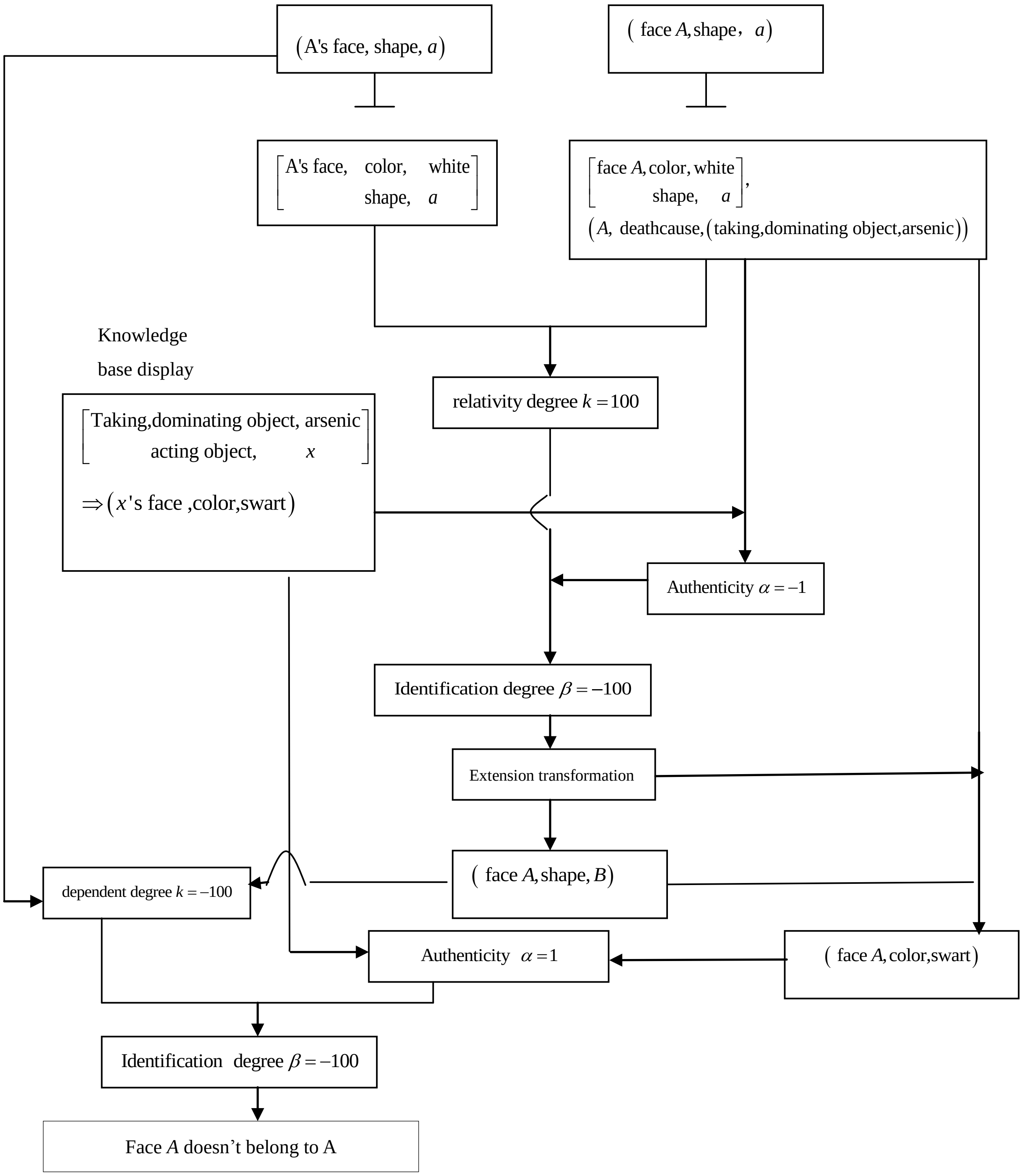


Figure 5.28 Flow of Identifying whether *A* belongs to A

After the investigator's careful observation, the neck of dead body *A* was found folded. Another face was found after ripping out the face skin and the color was swart. In fact, A's skin made of human skin was pasted on the face of B's corpse.

5.8.2 Application of Extension Methods in Search

1. Extension models of search problems

Search involves wide range, e.g. searching mineral resources in industry, search enemies or enemy weapons in military affairs, search criminal suspects or crime objects for public security department etc. Whatever search goals, the ultimate goal is to find unknown things, e.g. looking for mine, oil, airplane and criminals etc. That is to say, search problem is the seeking knowledge problem. Use contradictory problem

$$P = G_x * L$$

to present, G_x refers to the search goal and L is the search condition. Like the disposal of common incompatible problems, there are three ways to resolve search problems:

(1) Search from the goal to find problem solution.

(2) Start from the condition to find problem solution.

(3) Start from both goal and condition to find problem solution.

Search problem is usually very complicated. It involves the searcher, search goal and search environment. In the process of searching, we often meet all kinds of information. First, we need to present the information with basic-elements or their operations, judge information authenticity with the knowledge in knowledge base, and then extend more information with basic-element extensible rules and gradually find the search object. If the search object is person or human activity, we can study the strategies that may be taken by people to be searched (e.g. criminals) with basic-element transformations so as to find the people to be searched according to their strategies and corresponding information. We can also resolve contradictory problems occurred in the process of searching through combining extension methods with related professional knowledge.

2. General search steps with extension methods

Searching one object actually refers to find one object conforming to certain characteristics. For instance, searching person A refers to find the person that does something or with certain characteristics based on given conditions. In this process, extensible methods are adopted to reduce the unknown scope. Find the goal and judge information authenticity through transformations. Besides, unsearchable objects can be changed to searchable through transformations. The core is extension, transformation and matching. They carry out the simple flow repeatedly till successful search. The process is generally as follows:

(1) Establish extension models for search problem

$$P = G * L$$

Wherein, G refers to unknown goal basic-element $G = (O_x, c, v_x)$ and L refers to given condition basic-element.

For instance, the goal basic-element of one case is

$$G=\begin{bmatrix}\text{Search,} & \text{dominating object,} & I_x \\ & \text{acting object,} & a\end{bmatrix},$$

wherein $I_x=\begin{bmatrix}\text{steal,} & \text{dominating object,} & \text{cultural relic } A \\ & \text{acting object,} & O_x\end{bmatrix}$

Condition basic-element is

$$L=\begin{pmatrix}\text{shoe print,} & \text{length,} & 20\text{cm} \\ & \text{depth,} & 1\text{cm}\end{pmatrix}\wedge\begin{pmatrix}\text{car } B, & \text{license place,} & \times\times\text{ Army} \\ & \text{type,} & \text{truck}\end{pmatrix}$$

$$\wedge\begin{pmatrix}\text{tool } N, & \text{model,} & v_1' \\ & \text{function,} & \text{adsorbent glass}\end{pmatrix}$$

Thus this search problem is $P=G*L$.

(2) Make extensible analysis for the goal and condition of problem P

Make divergent analysis of G and L, write their one-object multi-characteristics basic-element. Then respectively establish correlative net to find their intersection and make goal implication analysis. Find the relation between goal uppermost basic-element and condition. Concrete steps are:

①Set the goal object of search as O and list given condition basic-elements (i.e. given information):

$$L_1=(O_1,\quad c_1,\quad v_1),\ldots,L_m=(O_m,\quad c_m,\quad v_m)$$

and possible goal basic-element:

$$G_x=(O_x,\quad d_x,\quad u_x)$$

② List the characteristics $d_1,d_2,\ldots,d_n$, to be confirmed for finding object O_x, then from divergent analysis we can get:

$$G_x \dashv G_x'=\begin{bmatrix}O_1, & d_1, & u_1 \\ & d_2, & u_2 \\ & \vdots & \vdots \\ & d_n, & u_n\end{bmatrix}$$

Wherein, $u_1,u_2,\ldots,u_n$ are undermined measure values.

③ Get the upper basic-elements of given condition basic-elements with implication method:

$$L_1=(O_1,\quad c_1,\quad v_1)\Leftarrow L_1'=\left(O_1',\quad c_1',\quad v_1'\right)$$

……

$$L_m=(O_m,\quad c_m,\quad v_m)\Leftarrow L_m'=\left(O_m',\quad c_1',\quad v_1'\right)$$

and upper basic-element of unknown goal basic-element:

$$G_x=(O_x,\quad d_x,\quad u_x)\Leftarrow G_x'=\left(O_x',\quad d_x',\quad u_x'\right)$$

④ Get related properties of each characteristic of upper basic-elements:

$$c_1' \sim c_{11}, c_{12}, ..., c_{1l_1}$$

…….

$$c_m' \sim c_{m1}, c_{m2}, ..., c_{ml_m}$$

$$d_x' \sim d_{x1}, d_{x2}, ..., d_{xp}$$

and confirm corresponding basic-elements of each characteristic:

$$\begin{bmatrix} O_1', & c_{11}, & v_{11} \\ & \vdots & \vdots \\ & c_{il_i}, & c_{il_i} \end{bmatrix},\quad (i=1,2,...,m)$$

$$\begin{bmatrix} O_1, & d_{x1}, & u_{x1} \\ & d_{x2}, & u_{x2} \\ & \vdots & \vdots \\ & d_{xp}, & u_{xp} \end{bmatrix}$$

(3) Confirm the initial goal

For the above process, make convergence based on restricted conditions: if

$$(O_x,\quad d_{xi},\quad u_{xi})\Rightarrow\left(O_x,\quad d_q,\quad u_q\right)\left(i\in\{1,2,...,p\}, q\in\{1,2,...,n\}\right),$$

then select characteristic $d_{q_i}, q_i\in\{1,2,...,n\}\left(i=1,2,...,s\right)$, confirm initial goal basic-element as

$$G_x=\begin{bmatrix} O, & d_{q_1}, & u_{q_1} \\ & d_{q_2}, & u_{q_2} \\ & \vdots & \vdots \\ & d_{q_s}, & u_{q_s} \end{bmatrix}$$

and then confirm initial goal set $\{O\}$.

(4) In initial goal set $\{O\}$, judge the search object with extension identification methods.

Get initial goal set $\{O\}$ according to (3) with extension identification methods in 3.4. For all $O \in \{O\}$, make identification and get the goal object to resolve the problem. If no $O \in \{O\}$ is the goal object, we need to find new clues through extension transformations and judge again. The way to make assisted search with various extension transformation methods is introduced in detail below.

3. Obtain new information aided search through extension transformation and its conductive transformation

In the process of searching, we should constantly find valuable information (clues). One way to find clues is investigation and the other is making new information appear through extension transformations. For instance, throw a stone to clear the road, draw a snake out of its hole, play cat and mouse, loose outside and tight inside and other transformation methods can make the opposite side take strategies to search the goal. On the other hand, the searcher often takes various methods to make the object to be searched expose related clue. All these are the results of conductive transformations. Therefore, another application of extension methods in search is offering numerous applicable extension transformation methods to the searcher to search the goal through conductive transformations. These transformations can be the cases accumulated from historical data, or those ruled by professional knowledge.

Give the problem $P = g * l$, make $\varphi l = l'$. If ${}_{\varphi}T_g g = g' \Rightarrow g$, we can resolve problem $P' = g' * l'$ first through transformation φ and then realize g, i.e. φ is the resolving transformation of problem P.

Now illustrate the way to assist search with various transformations and their conductive transformations through several examples.

[Example 5.7] A's left shoe was washed away by the river and then how to find it? A adopts the method below:

$$g = (\text{Search}, \quad \text{dominating object}, \quad \text{left shoe}),$$

$$l = \begin{bmatrix} \text{Wash away}, & \text{dominating object}, & \text{left shoe} \\ & \text{acting object}, & \text{river water} \\ & \text{position}, & \text{river } A \end{bmatrix},$$

$$M = (\text{River water}, \quad \text{speed}, \quad 5\text{m/s})$$

The problem is $P = g * (l \wedge M)$. Because

$$g \Leftarrow g' = (\text{Search}, \quad \text{dominating object}, \quad (\text{left shoe}, \quad \text{position} \quad a))$$

Wherein, $g' = (\text{Search}, \quad \text{dominating object}, \quad B)$, $B = (\text{left shoe}, \quad \text{position}, \quad a)$.

Make transformation

$$\varphi l = \begin{bmatrix} \text{Wash away,} & \text{dominating object,} & \text{right shoe} \oplus \text{rope} \\ & \text{acting object,} & \text{river water} \\ & \text{position,} & \text{river } A \end{bmatrix}$$

Thus following conductive transformation exists:

$$_{\varphi}T_B B = (\text{Right shoe,} \quad \text{position,} \quad a) = B',$$

$$_{\varphi}T_{g'} g' = (\text{Search,} \quad \text{dominating object,} \quad B') = g_1',$$

Obviously, $g_1' @ \Rightarrow g' @ \Rightarrow g @$.

Therefore, the searcher took one rope to fasten the right shoe on the one end and took the other end at hand. At the position where the left shoe was washed away, make river water push the right shoe fastened with rope toward the river bottom. Finally, the left shoe was found at the position of the right shoe fastened with rope.

Storage the information and knowledge about this kind of problems in strategy base after presenting them with basic-elements. Thus corresponding strategies for similar search problems can be found through establishing extension models with matching method.

[Example 5.8] To find the field mice hidden in subgrade hole, the peasants can adopt the following method:

Set the search problem as $P = g * l$, wherein

$$g = \begin{bmatrix} \text{Search,} & \text{dominating object,} & \text{field mice} \\ & \text{position,} & \text{subgrade hole } D \end{bmatrix}, \quad l = (\text{Field mice,} \quad \text{position,} \quad \text{in } D),$$

Make transformation $\varphi(hole) = hole \oplus water$, then there must be the following conductive transformation:

$$_{\varphi}T_l l = (\text{Field mice,} \quad \text{position,} \quad \text{hole} \oplus \text{water}), \quad _{\varphi}T_l^{(2)} l = (\text{Field mice,} \quad \text{position,} \quad \text{hole}),$$

Then there is a conductive transformation

$$_{l}T_g g = \begin{bmatrix} \text{Search,} & \text{dominating object,} & \text{field mice} \\ & \text{position,} & \text{hole} \end{bmatrix}$$

That is, pour water on mice to make them crawl to the entrance of a hole and get caught by peasants.

There are lots of similar examples, e.g. drive beasts through setting the mountain on fire, make fake fire disaster to force criminal suspects to leave the house etc.

[Example 5.9] A robbery case occurred in residential area *B*. Then take tight security, but the criminal couldn't be found. Later, "the practice of loose outside and tight inside" was adopted, which made the thief become careless. Then he committed a crime again and got caught finally. The process can be shown as follows:

Set the search problem as $P = g * (l_1 \wedge l_2)$, wherein

$$g=\begin{bmatrix}\text{Catch,} & \text{dominating object,} & \text{criminal suspect } A\\ & \text{position,} & \text{residential area } B\end{bmatrix}$$

$$l_1=(\text{Residentia area } B, \quad \text{atmosphere,} \quad \text{tight security})$$

$$l_2=\begin{bmatrix}\text{Criminal suspect,} & \text{crime intention,} & \text{weak}\\ & \text{position,} & \text{unknown}\end{bmatrix}$$

Make

$$\varphi l_1=(\text{Residential area } B, \quad \text{atmosphere,} \quad \text{normal})=l_1'$$

Due to $l_1 \sim l_2$, then a conductive transformation must exist

$$_{\varphi}T_{l_2}l_2=\begin{bmatrix}\text{Criminal suspect } A, & \text{crime intention,} & \text{strong}\\ & \text{position,} & \text{residential area } B\end{bmatrix}=l_2'$$

and

$$l_2' \Rightarrow \begin{bmatrix}\text{Steal,} & \text{dominating object,} & \text{property}\\ & \text{acting object,} & \text{criminal suspect } A\\ & \text{position,} & \text{residential area } B\end{bmatrix}=l_2''$$

Thus $g * l_2''$ becomes compatible problem and the purpose of catching criminal suspect in residential area B is realized. That is, make the criminal suspect relax, commit crime and get caught through the arrangement of “loose outside and tight inside”.

There are lots of similar examples. Present them with extension models and establish strategy base. Thus various selectable programs for making search strategies can be offered to the searcher, which is very valuable in criminal investigation, military affairs, exploration and other fields.

5.8.3 Application of Extension Methods in Diagnosis

The diagnosis of fault or disease (generally called fault diagnosis) aims to judge the faults and fault reasons in operation system. For instance, judge the abnormal situation in the operating process of machine (including fault location and fault type); diagnosis of human disease (including the diagnosis of specific organs and disease type etc.). Most current fault diagnosis is based on professional knowledge, experience of professional personnel or instrument. With the development of science, through the combination of extension methods and knowledge in practical fields, we can diagnose fault reason and fault degree according to certain procedures or rules, which will improve the accuracy of diagnosis.

1. Application objects of extension methods in diagnosis

Diagnosis of disease and fault aims to: (1) Judge the focus or fault source; (2) Judge the disease or fault type.

The former belongs to the search field and the latter belongs to the range of identification. It can thus be said that diagnosis is the integration of search and identification.

In diagnosis process, we often meet these problems: the change of climate, mood and drug effect make certain disease change and cause error diagnosis. The way to diagnose disease and fault under transformations is a problem which needs to be carefully studied.

On the other hand, in some diagnosis processes, we often transform objects that cannot be diagnosed to diagnosable through certain transformations. For instance, to diagnose human disease, we inject developer before examination. In CT examination, it can obviously display the position and shape of the focus; to examine the “ants’ cave” on the dam, we often adopt “pouring method” to assist the diagnosis.

Generally speaking, following three aspects are mainly discussed in the application of extension methods in diagnosis: study the diagnostic method under transformations; search the focus or fault source through the application of extension methods in search; identify fault type through extension identification methods.

2. Attempt at fault diagnosis with extension methods

In reference [9], one way to make system fault diagnosis with extension methods is introduced. It confirms fault type mainly through the integral analysis of fault objects. Conjugation analysis is then used to confirm fault position. The integral evaluation is made to confirm the fault position and degree.

The research on system fault diagnosis with extension methods is still at an early stage. Above all, diagnosis problem under transformations is more important while there is no related reference. Interested readers can make intensive study with reference to related references.

Symbol Description of

Extension Engineering

Signs	Meaning		Signs	Meaning
$M=(O_m, c_m, v_m)$	1-dimensional matter-element		$\mathrm{cp}M(O_m)$	the all characteristics matter element of matter O_m
$M(t)=(O_m(t),c_m,v_m(t))$	1-dimensional parametric matter-element		$B=(O, c, v)$	1-dimensional basic-element
$A=(O_a, c_a, v_a)$	1-dimensional affair-element		(c, v)	the characteristic-element of object O_m.
$A(t)=(O_a(t), c_a, v_a(t))$	1-dimensional parametric affair-element		$B(t)=(O(t),c,v(t))$	1-dimensional parametric basic-element
$M=\begin{bmatrix} O_m, & c_{m1}, & v_{m1} \\ & c_{m2}, & v_{m2} \\ & \vdots & \vdots \\ & c_{mn}, & v_{mn} \end{bmatrix}=(O_m,C_m,V_m)$	n-dimensional matter-element		$B=(O, C, V)=\begin{bmatrix} Object, & c_1, & v_1 \\ & c_2, & v_2 \\ & \vdots & \vdots \\ & c_n, & v_n \end{bmatrix}$	n-dimensional basic-element
$A=\begin{bmatrix} O_a, & c_{a1}, & v_{a1} \\ & c_{a2}, & v_{a2} \\ & \vdots & \vdots \\ & c_{an}, & v_{an} \end{bmatrix}=(O_a,C_a,V_a)$	n-dimensional affair-element		$B(t)=(O(t), C, V(t))=\begin{bmatrix} O(t), & c_1, & v_1(t) \\ & c_2, & v_2(t) \\ & \vdots & \vdots \\ & c_n, & v_n(t) \end{bmatrix}$	n-dimensional parametric basic-element
$R=\begin{bmatrix} O_r, c_{r1}, v_{r1} \\ c_{r2}, v_{r2} \\ \vdots, \quad \vdots \\ c_{rn}, v_{rn} \end{bmatrix}=(O_r, C_r, V_r)$	n-dimensional relation-element		$\{B\}=\begin{bmatrix} \{O\}, & c_1, & V_1 \\ & c_2, & V_2 \\ & \vdots & \vdots \\ & c_n, & V_n \end{bmatrix}=(\{O\}, C, V)$	n-dimensional class basic-element
$£(M)$	the whole matter-element		$\mathrm{re}(O_m)$	real part of matter
$£(A)$	the whole affair-element		$\mathrm{im}(O_m)$	imaginary part of matter
$£(R)$	the whole relation-element		$\mathrm{hr}(O_m)$	hard part of matter
$£(C_O)$	the whole compound-element		$\mathrm{sf}(O_m)$	soft part of matter
$£(B)$	the whole basic-element		$\mathrm{lt}(O_m)$	latent part of matter
$V(c)$	the domain of measure of c_m.		$\mathrm{ap}(O_m)$	apparent part of matter

$T\Gamma = \Gamma'$	substitution transformation		$ps_c(O_m)$	positive part of matter
$T_1\Gamma = \Gamma \oplus \Gamma_1$	increasing transformation		$ng_c(O_m)$	Negative part of matter
$T_2\Gamma = \Gamma \ominus \Gamma_1$	decreasing transformation		$=$	equal
$T\Gamma = \alpha\Gamma$	expansion/ contraction transformation		$\neq$	Not equal
$T\Gamma = \{\Gamma_1, \Gamma_2, ..., \Gamma_n \mid \Gamma_1 \oplus \Gamma_2 \oplus ... \oplus \Gamma_n = \Gamma\}$	decomposition transformation		$\sim$	correlative
$T\Gamma = \{\Gamma, \Gamma^*\}$	duplication transformation		$\tilde{\rightarrow}$	The directional correlation
T_φ	the first-order conductive transformation of active transformation φ		$\Rightarrow$	imply
$T_{\varphi^{(n)}}$	the n-order conductive transformation of active transformation φ		┤	extend
${}_{\Gamma_1}T_{\Gamma_2}$	the transformation of Γ_1 cause the conductive transformation of Γ_2		♁	Increase
$\varphi \Rightarrow {}_0T_1 \Rightarrow {}_1T_2 \Rightarrow \cdots \Rightarrow {}_{n-2}T_{n-1} \Rightarrow {}_{n-1}T_n$	n-order conductive transformation of φ		$\otimes$	Constitute system
T_2T_1	INTEGRAL transformation of T_1 and T_2		Θ	deletion
T^{-1}	REVERSE transformation of T		//	decomposition
$T_1 \wedge T_2$	AND transformation of T_1 and T_2		@	realization
$T_1 \vee T_2$	OR transformation of T_1 and T_2		$\overline{@}$	do not realize
$c(\varphi) = c(B_0') - c(B_0)$	the active variable of φ about c		$\wedge$	AND
$c(T_\varphi) = c(B') - c(B)$	first-order conductive effect about characteristic c		$\vee$	OR

$\tilde{E}(T)$	extension set		$\neg$	NON
E_+	positive field of $\tilde{E}$		$A \dashv B$	A extends B
E_-	negative field of $\tilde{E}$		$A \vDash B$	A deduces B
E_0	zero boundary of $\tilde{E}$		$\overline{B}$	non-basic-element of B
$\underset{\cdot}{E}_+(T)$	positive extensible field (or positive qualitative change field)of $\tilde{E}(T)$;		$\overline{M}$	non-matter-eleme nt of M
$\underset{\cdot}{E}_-(T)$	negative extensible field(or negative qualitative change field) of $\tilde{E}(T)$;		$\overline{A}$	non affair-element of A
$E_+(T)$	positive stable field (or positive quantitative change field) of $\tilde{E}(T)$		$\overline{R}$	non relation-element of R
$E_-(T)$	negative stable field (or negative quantitative change field) of $\tilde{E}(T)$		$y=k(u)$	dependent Function
$E_0(T)$	extension boundary of $\tilde{E}(T)$		$y'=T_k k(T_u u)$	extension function
$\tilde{E}(B)(T)$	basic-element extension set		$\rho(x, X)$	extension distance between x and the interval X
$D(x, X_0, X)$	the place value of point X about the nest of intervals composed of intervals X_0 and X		$\rho(x, x_0, X)$	side distance between x and X about x_0
$P=G*L$	incompatible problems		$<a, b>$	the notation of the interval $<a, b>$ used in this book, which is slightly different from that in classical mathematics, indicates open interval, closed interval, or half-open and half-closed

				interval.
$P=(G_1 \wedge G_2)*L$	antithetical problem			

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