EVOLUTIONARY THINKING AND CHANGES OF THE TIME SCALE IN REPRESENTATIONS OF THE WORLD

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Abstract

In this work, emergence of evolutionary thinking is analyzed in the context of the existential triad and system theory of time. This approach shows that emergence of evolutionary thinking is a transition from one type of temporal scale in the mental world representation to another temporal scale. To explain and ground this transition, elements of the system theory of time, which is a far-reaching development of the special relativity theory, are described. One of the main principles of the special relativity theory is that two physical systems that are moving relative to each other have different time and it is necessary to use a correspondence between clocks in these systems to coordinate their time. In accordance with the basic principles of the system theory of time, each system has its own time and sometimes even not a single one. Thus, it is it is necessary to use various techniques to match time in different systems.

Key words: time, system, evolution, development, relativity, inner time, external time, scale of time, system time

1. Introduction

Anthropological studies show that primitive tribes had a static world comprehension. According to it, the world was created and since that event, nothing has been changing. It is easier to think that nothing changes at all. However, this contradicts to the everyday experience. People can see many changes. For instance, day changes to night, which in turn, changes to another day and the whole process repeats all the time. Seasons (spring, summer, fall, and winter) are changing one another also forming an infinitely repeating cycle. All these phenomena instigate formation of the world comprehension based on some kind of cyclic time. Cyclic time, in which everything is repeating itself, has become a cornerstone of the world picture in social and individual mentality for millennia.

Evolutionary thinking changes the world comprehension by breaking the existing temporal cycle. The new vision brings understanding of time with a very different nature. For instance, Bergson makes a special emphasis on the distinction between the reversible time of physics, in which nothing new happens, and the irreversible time of evolution and biology, in which there is always something new (Bergson, 1910). A lot has been written about the arrow of time, which goes from the past to the future through the intangible present (cf., for example, (Savitt, 1997; Stengers and Prigogine, 1997)).

To explain peculiarities of this process and its relation to physical time, we utilize the concept of the existential triad, which provides the upper level of the world stratification (Burgin, 1997; 2012). The system theory of time (Burgin, 2002) supplies means for understanding geometry and topology of evolutionary time and its impact on people's mentality.

2. Introductory Principles of the System Theory of Time

Here we present only those principles of the system theory of time that allow us to understand evolutionary thinking and its emergence. Our understanding and modeling of time is based on the concept of the fundamental triad (named set) as well as on the methods and apparatus of named set theory (Burgin, 1990; 2011). That is why, for completeness of exposition, we introduce and explain some concepts from this theory, as well as from theory of abstract properties (Burgin, 1990a).

At first, the structure of the fundamental triad was explicated in a general form in mathematics and was called "*a named set*" (Burgin, 1990; 2011). This concept appeared in a process of development and unification of important mathematical fields such as fuzzy set theory and theory of multisets. In such a way, a new structure - named set - was introduced, encompassing fuzzy sets and multisets. Later it was called, a *fundamental triad* (Burgin, 1997).

Definition 1. A *fundamental triad* has the following structure:

$$\textbf{Entity 1} \xrightarrow{\textbf{connection}} \textbf{Entity 2} \qquad (1)$$

or

$$\textbf{Essence 1} \xrightarrow{\textbf{correspondence}} \textbf{Essence 2} \qquad (2)$$

Each component of a fundamental triad plays its unique role and has a specific name: the Entity 1 (Essence 1) is called the *support*; the Entity 2 (Essence 2) is called the *reflector* (or the *component of names*); and the connection (correspondence) is called the *reflection* (or the *naming relation*) of the fundamental triad. Thus, a named set **X** consists of three components **X** = (X, f, I) where X is the *support*, I is the *component of names*, and f is the *naming correspondence* of the named set **X**.

There are different formal mathematical definitions of named sets: in the theory of categories (Burgin, 1990), theory of sets (Burgin, 2004), and as an axiomatic theory based on the first-order logical predicate calculus (Burgin, 1993).

Many mathematical systems are particular cases of named sets or fundamental triads. The most important of these systems are relations, functions, graphs and hypergraphs (Berge, 1973), and fiber bundles (Husemöller, 1966), as well as such natural generalizations of the concept of a set as fuzzy sets (Zadeh, 1965), multisets (Aigner, 1979; Blizard, 1991), Boolean valued sets (Abian, 1975; Bell, 2005), Chu spaces (Barr, 1979). All these structures are very important for mathematics and have many diverse applications. Moreover, any ordinary set is, as a matter of fact, some named set, and namely, a singlenamed set, i.e., such a named set in which all elements have the same name (Burgin, 2004; 2011).

At the same time, people meet named sets (fundamental triads) constantly in their everyday life, as well as they can found them in many fundamental structures of the universe. They can even see some of fundamental triads (named sets) (Burgin, 1996; 1997; 2011).

Theory of named sets makes it possible to give an exact definition of such a widely used notion as '*property*' and to develop mathematical theory of properties, which includes logic as its subtheory (Burgin, 1990a).

Let **U** be some class (universe) of objects, and **M** be an abstract class of partially ordered sets, i. e., such a class that with any partially ordered set contains all partially ordered sets which are isomorphic to it.

Definition 2. An *abstract property* P of objects from some universe **U** is a named set P = (**U**, *p*, *L*) where *p* is a partial function (*L*-predicate), which is called the *evaluation function* of the property P, has **U** as the *domain* (or the *universe*) and some partially ordered set $L \in$ **M** as the codomain, which is called the *scale* of the property P. That is, *p* is defined in **U** and takes values in *L*.

We denote the scale of the property P by Sc(P) = *L*, the universe of the property P by Un(P) = **U**, and the evaluation function of the property P by Ev(P) = *p*.

Named sets and abstract properties form a foundation for the mathematical component of the system theory of time.

An important peculiarity of the system approach to time is the emphasis that is made on the necessity to consider time not as an absolute essence but to relate time to a definite system. So, let us consider some system *R* and discuss relations between time *T* and system *R*.

Principle OT 1 (Systemic Principle)**.** *Any system has its own time*.

Applied to physical systems, Principle OT1 implies that in different coordinate systems time is different and it is necessary to assign one local time to the other in order to coordinate events in these systems. The special theory of relativity determines how to do this coordination. According to the special theory of relativity, the notion of time relies on clocks, the date of an event being defined by coincidence of this event with a top delivered by a clock located at the same place. In order to be defined in the whole space, the notion of time also relies on the exchange of light signals, which are necessary to compare and synchronize the indications of remote clocks. The universal and finite velocity of light propagation then leads to a definition of time simultaneity, which depends on the observer's motion. In other words, time simultaneity is not given a priori but results from a construction, or clock synchronization. By exchanging light signals, on which time references provided by clocks are encoded, one can compare these references and synchronize clocks. In this sense, the system theory of time is an extension of the special theory of relativity.

To derive other properties of time from Principle OT1, we apply system theory. According to its principles, any system **R** is not unique, if we exclude the system of everything, which in some sense is ill defined. Consequently, there is another system **Q**, which is not included in **R**. In general, we have the following triad

$$\mathbf{R} \ \overset{\textbf{interaction}}{\rightleftarrows} \ \mathbf{Q} \qquad (3)$$

Principle OT1 implies that **R** has some time $T_{\mathbf{R}}$, **Q** has some time $T_{\mathbf{Q}}$, and interaction as a system has some time $T_{\mathbf{RQ}}$. If we consider $T_{\mathbf{R}}$, $T_{\mathbf{Q}}$, and $T_{\mathbf{RQ}}$ with respect to **R**, then we come to the following result.

Theorem 1 (Burgin, 2002)**.** *Three types of time exist for an arbitrary system* **R**: *an internal, connection, and external time.*

Here, $T_{\mathbf{R}}$ is an *internal time* for **R**, T_{Q} is an *external time* for **R**, and T_{RQ} is a *connection time* for **R**.

Let us give exact definitions

Definition 3. *Internal time* $T_{\mathbf{R}}$ of **R** is the time, in which the whole system **R** or some of its subsystem functions.

Definition 4. *External time* $T_{\mathbf{eR}}$ for **R** is an internal time of its environment as a system.

From this definition, it follows that an external time for **R** is an internal time of any system that is not included in **R**.

Definition 5. *Connection time* $T_{\mathbf{cR}} = T_{\mathrm{RQ}}$ for **R** is the time in which the processes of interaction of **R** with its environment go on.

An external time for a system **R** is the inner time $T_{e\mathbf{R}}$ of any system **Q**, which is not a subsystem of **R**. However, the system **Q** may be unrelated to **R**. In this case, times in these systems also look unrelated to **R,** while by Definition 4, they are attributed to **R**. Thus, to eliminate this difficulty, we introduce a proper external time $T_{pe\mathbf{R}}$.

Definition 6. A proper external time $T_{pe\mathbf{R}}$ for a system **R** is the inner time $T_{\mathbf{Q}}$ of any system **Q**, which contains **R.**

A union of two systems may be considered as a system containing both initial systems. So, we have the following result.

Proposition 1 (Burgin, 2002). *For any system* **R**, *there is a proper external time.*

Internal, or inner, time $T_{I\mathbf{R}}$ is an inherent property of the system **R**. Several kinds of inner times are connected with such a system as a human being. There is biological time, which is the inner time of an individual when we consider this individual as a biological (living) system. Besides, researchers distinguish physiological time if the organism of a human being is considered on the level of biochemical (physiological) process (Winfree, 1986). If we consider a human being as a biochemical system, then such a kind as the biological time is the primary one (Sutton and Ratey, 1998; Winfree, 1986). Psychological time appears on the level of personality (Burgin, 1997), while the behavioral level of individual is related to perception time, as well as to reaction time (Bragina and Dobrohotova, 1988).

Existence of several inner times in one individual implies that the age of a person is not a unique number, which is equal to the length of physical time from the birth of this person to the given moment. This is only the chronological age, which is not the most important for a human being. Much more important are biological, physiological, and psychological ages of a person. Biological age reflects how the organism of this person is functioning. Physiological age represents how biochemical reactions are going in the organism of this person. Psychological age reflects how the psyche of this person is functioning.

A cause of external time $T_{e\mathbf{R}}$ existence is that the system **R** is not unique – there are other systems. Time in any of these systems is an external time $T_{e\mathbf{R}}$ for **R** . For example, any living being **B** has its internal time. At the same time, **B** is a part of nature and lives in physical time, which is external time $T_{e\mathbf{R}}$ for **B**.

Connection time $T_{c\mathbf{R}}$ is the time in which goes interaction. It exists only for such pairs of systems, which interact. For example, connection time $T_{c\mathbf{R}}$ of a person **B** with the car, this person is driving, is neither the internal time of **B** nor the physical time, which is the external time for **B**. Time $T_{c\mathbf{R}}$ depends on perception and reaction of the person. Consequently, it might be different for different persons even with the same car.

Existence of three types of time is a peculiarity of both nature and society. To reflect and model inner time in physical systems, a mathematical construction was introduced in (Prigogine, 1980). Besides, inner time is discussed and utilized in the chronogeography (Parks and Thrift, 1980), as well as in biology and physiology (Sutton and Ratey, 1998; Winfree, 1986). Moreover, experiments demonstrate relative independence of the inner biological time from the external physical time (Winfree, 1982).

To reflect properties of different kinds of time, the system theory utilizes principles, which represent the most essential properties. We begin with principles for inner time. The main principle connects the flow of the inner time in a system with changes going on in this system.

Principle OT 2 (`Dynamics Principle`)**.** *Time* $T_{\mathbf{R}}$ *in a system* **R** *is a property of* **R** *in which the scale* L_T *is labeled/indexed set (in particular, a sequence) of changes in* **R.**

This corresponds to and develops further the traditional approach, in which time is reckoned by noting the intervals that occur by the motion of material things. Historically, this has meant how many times the sun is at its highest point in the sky (days), the moon at the same phase (month), and the passing of the seasons (year). In the physical world, recognition of the passage of time is always in relation to something material. Taking the motion of material things as a time indicator, we see that the more uniform the material motion the more accurate we can be in our measurements and divisions of time.

Principle OT2 correlates with ideas of Zwart (1976), Meyen and Sharov (1995), who define time as a sequence of all events or states of the system. However, these approaches have several shortcomings. First, the notion of event is not sufficiently exact for a scientific concept. Second, Zwart assumes existence of the absolute time. Relativity theory invalidated idea of the absolute time, demonstrating that even physical time in different systems might be different. Moreover, according to Zwart, there is only linear time, while, for example, biological time is cyclic in many cases. Later we will see that there are many other kinds of nonlinear time.

Definition 7. A property P of the system **R** is called an *ontological base* of time T if changes of P determine the flow of time T.

That is, any change of P is implied by a change of T and any change of T on a unit element corresponds to a unit change of the value of P, i.e., one unit adds to the quantity of time. An ontological base P of T is denoted by P = Ont (T) and T is called the P-time of the system **R**.

In hierarchic systems on different levels of hierarchy, specific properties exist, which are ontological bases for the corresponding kinds of time.

In general, it is possible to correspond some inner time T of **R** to any property P of **R** taking P as the ontological base of T. But formally, it does not mean that any inner time of **R** is of the same kind.

Existence of an ontological base for an inner time is stated in the following principle.

Principle OT 3 (General Ontological Principle). *For any system* **R** *and any time* $T_{\mathbf{R}}$ *the ontological base* Ont ($T_{\mathbf{R}}$) *of* $T_{\mathbf{R}}$ *exists*.

From this principle follows an important consequence: a moment (a unit) of inner time does not mean a position, in which the system **R** is in some state, but a point (a unit) at which a change of **R** is going on. Only for an external time, we may say that **R** is in a given state at some moment.

Nevertheless, a moment (a point, an interval) t of time $T_{\mathbf{R}}$ may be corresponded to two states of **R** : the source state u and the final state v. As a result, the model of I has the form of the named set $t = (u, \text{ch}, v)$ where ch is the change of **R** which transforms u into v at the moment t . Here $u = S(t)$ is the support of t and $v = N(t)$ is the reflector of t. If t is a moment (a point) of time $T_{\mathbf{R}}$, then we denote it by $t \in T_{\mathbf{R}}$. So, the scale $Sc(T_{\mathbf{R}})$ of the property "time," denoted by the letter T, is a system of named sets, and each interval of the system $Sc(T_{\mathbf{R}})$ is represented by some named set.

Proposition 2 (Burgin, 2002). *Representation of intervals by named sets is one-to-one correspondence if and only if the* Sc(T) *is a linearly ordered set*.

Time with other types of the scale is considered in literature. The most popular type is branching time (De Bakker, *et al*, 1984; Bergstra, *et al*, 2003; Burgin, 2001; Van Globbeck, 1994). It is very popular in computer science and a little by little coming to physics.

For a physicist (cf., for example, (Einstein, *et al*, 1923; Hawking, 1998)), time is something that is measured by clocks. Such understanding is implied by the following principle.

Principle OT 3c (`the constructive ontological principle`). The scale L_T of the time $T_{\mathbf{R}}$ *is a set (a sequence) of detectable states of some subsystem* **C** *of* **R**, *which is called the clock for* $T_{\mathbf{R}}$.

Studying and discussing physiological and biological times scientists introduced such term as "inner clocks" of an organism (Richter, 1968; Winfree, 1986). They relate these clocks to circadian rhythms in the brain (Winfree, 1983; Takahashi and Zatz, 1982).

More restricted is the following principle.

Principle OT 3d (`the strict ontological principle`). *Any inner time* $T_{\mathbf{R}}$ *in a system* **R** *is the system of changes of some property* P *of* **R**.

There has been also a debate whether the scale L_T of time is continuous or discrete. Although continuous time scale has been always more popular, esoteric medieval directions, as well as some classical philosophical schools in India, preferred discrete conception of time (Kosareva, 1988). Now some theories of quantum physics also utilize discrete models of time (Blokhintsev, 1982; Vyaltsev, 1965).

It is interesting to mention that Eddington suggested a hypothesis (cf. (Chernin, 1987)) that time is one-dimensional only in some cosmic neighborhood of the Earth, while time may be two-dimensional in some very distant domains of the universe.

In science as a epistemological mechanism, time connected with changes of the knowledge system is the most important. It is called the *gnostic* time and is determined by changes in the knowledge system **K** of science. Now there are no means of precise definition of the gnostic time because means of knowledge measurement and even of its evaluation are not developed enough. But development of such means will provide a possibility for elaboration of clocks for the gnostic time.

Taking instead of the whole knowledge system of science its subsystem related to some object field (for example, physics or science of science). We obtain the notion of the field gnostic time.

Systems are usually represented in a parametric form. That is, a system **R** is reflected in knowledge systems (like theories) by means of a collection of parameters or attributes. Values of these parameters/attributes give the states of the system **R**. Any parametric/attributive representation is a representation by means of properties because parameters/attributes are some kinds of abstract properties. Moreover, the general theory of properties makes possible transformation of any symbolic representation of the system **R** into an attributive representation (Burgin, 1990). In it, a collection of properties **P**(**R**) is corresponded to **R** and values of these properties reflect the states of the system **R**. Theorem 1 implies the following result.

Theorem 2 (Burgin, 2002). *Any parametrical/attributive representation of a system* **R** *is equivalent to a representation of* **R** *by means of a single property.*

An ontological base Ont(T) may be treated as the state vector (a vector representation) of **R** in some state space.

Proposition 3 (Burgin, 2002). *Uniqueness of all moments of time is equivalent to absence of loops in the structure of time.*

Definition 8. A system **R** is called

a) *primitive* if it is completely represented by a single one-dimensional property;

b) *multidimensional* when any property, which completely represents P, is multidimensional (Burgin, 1990).

Remark 1. A multiaspect system can be primitive if different aspects are reduced to a single property.

Proposition 4 (Burgin, 2002). *In a multidimensional system* **R** *there are different inner times or, equivalently, time may be multidimensional, as an abstract property.*

Many examples of this situation are demonstrated in (Burgin, 1997a) where a complex natural system is treated as a complex of hierarchical subsystems. Thus, in natural systems different kinds of time appear. Each kind corresponds to some hierarchical level of the given system. But, as states Proposition 10, different times may exist even on one hierarchical level. Relativity theory gives examples for such situations (Einstejn, Lorentz, Weil, and Minkowski, 1923). If we consider a physical system **R** consisting of two subsystems that are moving with a very big velocity in opposite directions, then these subsystems have different time although it is possible to determine correspondence between these times by means of light signals.

A more exotic model of time is suggested in the branching space-time interpretation of quantum mechanics (Belnap, 1992).

Computer networks give another interesting example of a system in which its subsystems, in particular, network nodes, have their individual time. This individual time of network nodes is called logical time of the node and measured by hardware clocks (Simons, Welch, and Lynch, 1990; Dobbelaere, Kearns, and Mayo, 2003). Moreover, it is even impossible to completely reduce this multiplicity of times to one unique time as it is demonstrated that hardware clocks cannot be perfectly synchronized (Welch, and Lynch, 1988). However, the clocks can be roughly synchronized so that the difference in the readings of any two clocks at an instant of physical time (the clock skew) is kept within some known bound (Ramanathan and Shin, 1990; Simons, Welch, and Lynch, 1990).

Besides, the whole network has its own time. This time was introduced by Lamport (1978) and called *logical time* of a network. As a rule, it is different from physical time. The main idea of introducing logical time is necessity to order events in distributed systems. In addition to global logical time and individual node time, the concept of local time, i.e., common time for some neighborhood of nodes is used in computer networks, is used. Moreover, full logical time is also introduced (Dobbelaere, Kearns, and Mayo, 2003). Logical time clocks are synchronized only by routing messages. This implies that once the network reaches a stable state, logical clock values will not be updated again until a link failure occurs. In contrast to this, working in full logical time, the network updates clocks are synchronized by all messages.

Time dependencies and time scales are important in a lot of areas. This is just a case for the brain functioning. As found neurophysiologists working together with mathematicians (Cipra, 2001), it may well be that the brain does its job in large part by synchronizing the rhythmic firing patterns of spatially distant cells. As it is known, the brain contains a huge mesh of excitatory and inhibitory neurons, which communicate across small gaps called synapses. Roughly speaking, when an excitatory neuron ”fires” (that is, when the voltage across its membrane spikes), the neurotransmitters it spews at its synapses lift the neighboring neurons toward their own firing thresholds. Conversely, an inhibitory neuron tends to depress the cells around it. What is crucial is that multiple time scales are involved, those intrinsic to the cell membrane and those associated with the synaptic signals. The interaction of these time scales is responsible for some counterintuitive results. For example, a network of purely inhibitory neurons can wind up firing in synchrony, even though the cells are ostensibly telling each other not to fire at all.

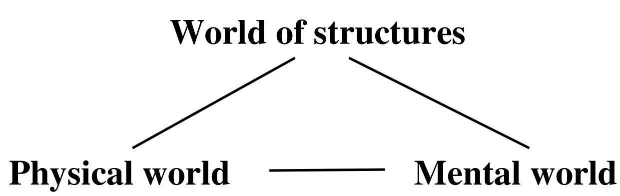
This correlates with a hypothesis of Winfree (1986) that an individual has many different inner clocks that induce different times in subsystems of the organism.

3. The Global World Structure and Topology of the Time Manifold

In the Plato tradition, the global world structure has the form of three interconnected worlds: *material*, *mental*, and the *world of ideas* or *forms*. Modern science makes it possible to achieve a new understanding of Plato ideas. With respect to the existential triad stratification, the material world is interpreted as the physical reality, while ideas or forms are corresponded to structures (Burgin, 1997; 2012).

In the mental world, there are real "things" and "phenomena". For example, there exist happiness and pain, smell and color, love and understanding, impressions and images (stars, tables, chairs and etc.). In the physical world, there are the real tables and chairs, sun, stars, stones, flowers, butterflies, space and time, molecules and atoms, electrons and photons. It is demonstrated (Burgin, 1997) that the world of structures also exists in reality. For instance, the fundamental triad exists in the same way as tables, chairs trees, and mountains exist.

Thus, the global structure of the world has the form of the existential triad:



Each of these worlds has a hierarchical organization and contains representation of two other worlds. It is an important peculiarity of the world (as a whole) that it exists in such a triadic form not as static but as a dynamic structure. As the result, time exists in all three worlds. We know a lot about time in physical systems, although we do not know everything. So, different theories of time in the universe are suggested

Mental world, as a whole, and individual mental worlds of people also have specific times. Mental time is known less, but it is also considered in literature (cf., for example, (Priestley, 1968)). Mental time of conscience is known as psychological time (e.g., Golovaha and Kronik, 1984). Evolutionary thinking depends on the mental representation (model) of the physical time as thinking is a process in the mental world on the individual level.

There are more problems with understanding temporal aspects in the World of structures because this world was discovered only recently (cf. Burgin, 1996; 1997). The World of structures is a scientific form of Plato's World of ideas. Plato assumed that there is no time in this World of ideas. Some contemporary thinkers (cf., for example, Steinsaltz, 1996) make the same assumption with respect to mathematical knowledge. Nevertheless, time in the World of structures exists as there is a subsystem of physical structures, which is the projection of Physical world into the World of structures. In addition, there is the projection of Mental world into the World of structures. Mental world is changing in its time. This induces another specific time into the World of structures.

It is necessary to make a distinction between time in mathematical (scientific) knowledge and time in mathematics (science) as a social system. In the first case, we consider knowledge that exists in society at definite periods of its history. This knowledge changes. So, we have time in the system of knowledge. Moreover, this time is branching due to existence of different areas of knowledge represented by a variety of disciplines.

In the second case, any social system has its own systemic time, as well as a variety of times in its subsystems.

Remark 2. Now physics treats time in a conjunction with the physical space by forming as its model a unified space-time manifold (e.g., (Einstein *et al*, 1923; Penrose and Rindler, 1984)). It is also possible to combine space and time into one manifold in the system theory of time. Instead of the conventional physical space, this manifold must be based at the system state space. However, now system time is studied much less than physical time. So, it is reasonable at first to study system time and space separately and only having enough knowledge to synthesize them into one space-time manifold.

To introduce structure into time and study its properties by mathematical models, we accept the conventional set-theoretical mathematics. In it all objects are built as sets with elements. In particular, we consider only set-theoretical named sets, in which the support, and reflector are sets (topological spaces), while the reflection is a (continuous or fuzzy continuous) binary relation between these sets (spaces). As a rule, additional structures are introduced into the sets that are used for building mathematical models. Usually three types of structures are considered in mathematics (cf. Bourbaki, 1960): order, algebraic, and topological structures. In our case, time, or more exactly, the time scale becomes a set of time moments with some geometry or topology in it. As geometry is, in some sense, a specific case of topology, here we consider topological properties of time.

When time **T** is represented by the named set (T, tp, L_T), then L_T is called the *time manifold* or *temporal scale*, and moments of time **T** are inverse images of points from L_T . This representation transforms time **T** into a fiber bundle (e.g., (Hurewicz, 1955; Husemoller, 1966)) as it is natural to treat sets T and L_T as topological spaces. There are several interpretations of time that is related to evolutionary thinking. According to the first interpretation of the fiber bundle **T**, T is treated as a system time, e.g., physical time. Correspondingly, L_T is a representation of the physical time in the mental world when T is reflected in an individual or social conscience or in the structural world when T is reflected in a knowledge system. Note that in this case L_T is not mental time, but can be closely related to mental time and even influence it.

Another interpretation involves two fiber bundles: the space **T** = (T, tp, L_T) of the physical time and the space $\mathbf{T}_{\mathrm{m}}$ = (T_m , tp_m , L_{Tm}) of its model in a mental world. Then a *modeling homomorphism* (modeling homomorphic relation) exists between these two spaces (Burgin, 2001a).

Topology in the *time manifold* L_T is defined by relations between moments of time. There are different kinds of such relations: similarity, precedence, causality etc. Similar belief relations (e.g., assumed similarity, precedence, causality etc.) define topology in the time manifold L_{Tm} .

For simplicity, we consider here only one-dimensional time manifolds L_T . It is natural to separate three types of one-dimensional time topology:

1. *Linearly ordered time* (cf. Figure 1).
2. *Branching time* (cf. Figure 2).
3. *Net time* (cf. Figure 3), which includes *cyclic time* (cf. Figure 4).

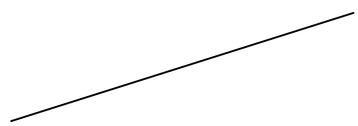


Figure 1. An example of linearly ordered time

For physical systems, linearly ordered time can be bounded, e.g., for a building, or unbounded, e.g., for the whole world. According to contemporary physical theories, physical time of our universe is bounded from below. Some physical theories assume that it is also bounded from above, although other physical theories conjecture that it is unbounded from above. Now we do not have enough evidence to make a grounded choice between these two possibilities.

Linearly ordered time is the most popular model of time. Usually, the conventional model assumes that the temporal scale L_T is the space $\boldsymbol{R}$ of all real numbers or its finite or infinite interval. In classical physics, linear time is reversible, while quantum theories and thermodynamics imply that L_T is a directed one-dimensional continuum. It is metaphorically called the arrow of time. The arrow of time has been directly measured by two groups of physicists, one at CERN in Geneva and one at Fermilab near Chicago (Schewe and Stein, 1998). The two groups have seen evidence for violation of time reversal in the observed decay rates for neutral K mesons.

Topological and metric considerations show that there are various shapes of linearly ordered time. For instance, a popular model is *spiral time* (cf. Figure 2).

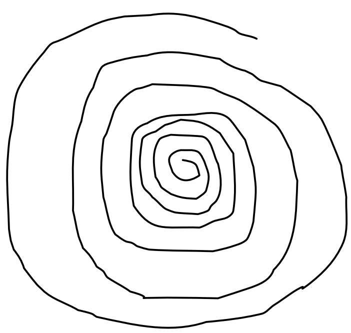


Figure 2. An example of two-dimensional spiral time

Branching time (Figure 3) has been studied in logic as a kind of abstract temporal logics (Prior, 1962; Von Wright, 1969). In a natural way, branching time emerges in computation (cf. (Burgin, *et al*, 2001)) and is modeled in computer science (e.g., (Bergstra, *et al*, 2003)). In physics, it is also necessary to consider branching time in connection with the many-worlds theory that states that reality consists of a steadily increasing number of parallel isolated universes (e.g., (DeWitt and Graham, 1973; Davies, 1980; Herbert, 1987)). In the original version of many-worlds, in the Ph.D. thesis of H. Everett (1957), the universe is in a pure state, not a density operator. The time-evolution is unitary. One can then list all possible values of every observable (that are consistent in the sense of quantum theory). Since it is assumed that time is continuous, this leads to a very large set of "consistent histories": in modern terms, one first chooses a maximal abelian subalgebra A of B(H) at each time, and a point in the joint spectrum at each time; the set of these choices is the sample space of an elaborate stochastic process. Then one does this for another maximal abelian algebra, and so on, until every possible experimental arrangement that might have been set up over all time has been included. Everett suggested that every branch actually occurred as a specific universe and is entirely invisible to all the others. Thus, each universe has its own time, which is linear, but time of the whole world is branching. In later days, Everett suggested that the many worlds were not actual but represented many views of the same world. The difference between the actual and virtual existence of multiple universes impacts our understanding of the time fiber space **T** = (T, tp, L_T). In the first case, both

T and L_T have the branching structure, while in the second case, only L_T has such a structure. The idea that the many worlds are actual was then taken up by DeWitt (1973) and other quantum theorists.

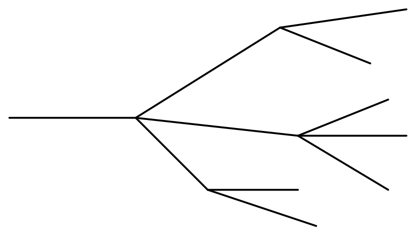


Figure 3. An example of branching time

Branching time is also an essential counterpart of the branching space-time interpretation of quantum mechanics (Belnap, 1992).

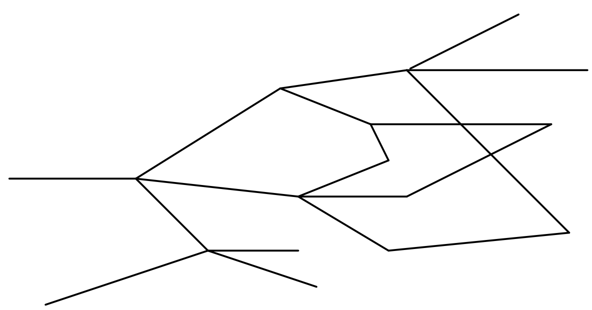


Figure 4. An example of net time

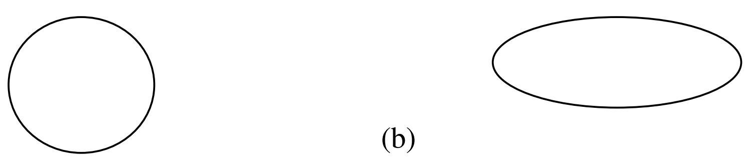
(a)  (b)

Figure 5. Cyclic time: (a) circular time and (b) elliptic time

For our purpose, we consider only two forms of linearly ordered time: *cyclic* and *unbounded* time.

Cyclic structure results in three temporal archetypes:

- *Circular time*, in which there is one cycle and everything repeats exactly.
- *Ring time*, in which there is one cycle and everything repeats within some reasonable boundaries.
- *Toroidal time*, in which two or more cycles appear.

Toroidal time shows a more complex and sophisticated pattern of repetition than circular time. An example of toroidal time is two-cyclic time where one cycle is defined by the periodical repetitions of days and nights and the second (longer) cycle results from the repetition of year seasons.

The repetition of year seasons induces elliptic time, which is a kind of ring time. In elliptic time, some temporal points are closer to one another than others. In the example with the repetition of year seasons, spring and autumn are closer to one another by their characteristics than winter and summer.

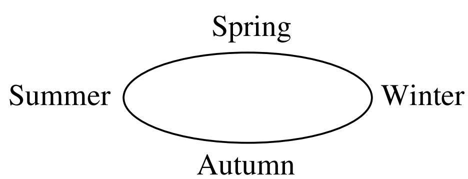


Figure 6. Seasonal elliptic time

In unbounded temporal structures, we distinguish three archetypes:

- *Linear time* when there are always something new.
- *Spiral time* when innovations go all the time, but they resemble (are similar to) what was before.
- *Multispiral time* in which there are several spiral structures.

Remark 3. Physicists suggest that topology in the space-time manifold depends on the underlying arithmetic (cf., for example, (Blokhintsev, 1982; Zeldovich, *et al*, 1990; Smolin, 1999)). Such an arithmetic can be non-Diophantine, i.e., its properties are different in comparison with the ordinary Diophantine arithmetic (Burgin, 1997; 2001). This correlates with system approach to time.

When the underlying arithmetic is non-Diophantine, properties of the space-time manifold change. This correlates with ideas of physicists. For instance, Blokhintsev (1982) writes that it is possible to induce such a geometry into the space-time manifold in which there is no additivity of intervals, e.g., AB + BC ≠ AC. As time and space intervals are represented by numbers, this inequality is possible only when the underlying arithmetic is non-Diophantine.

The system theory of time has important implications for biology. It allows one to decompose time into a multidimensional parameter and to represent age as a three dimensional vector of specific inner times of an individual (Burgin, 2004a). This model is called the *triadic age* as it has three components: biological, physiological, and psychological age.

4. Evolution and Evolutionary Thinking

To understand evolutionary thinking, we need to analyze the use of the term "evolution," which is so popular in science and beyond. For example, evolution is a common term used in celestial mechanics that refers to the decomposition of a body into two parts: evolution as a directed change, and oscillations that are relatively small (Arnold, 1997). Futuyama (1986) wrote: "In the broadest sense, evolution is merely change, and so all-pervasive galaxies, languages, political systems, etc., evolve." Contrary to this, the most popular understanding is that evolution is not "merely change," but possesses some additional properties. For example, many consider evolution as emergency or creation of new structures or species (Haken, 1983) rendering in such a way the innovative meaning of the term "evolution." Thus, we make a distinction between *evolution in a generalized sense* as any change and *evolution in the proper sense* as a change that involves emergence. Evolutionary thinking is related to evolution in the proper sense. However, even in a more restricted sense evolution refers to the main aspects of reality. We can speak of galaxies and chemical elements that evolve. People discuss such subjects as the evolution of computers and their software, evolution of political systems and laws.

It was probably Herbert Spencer who, in his "The Development Hypothesis" (1852), and "Principles of Psychology" (1855), first suggested the application of evolution to every field of study. As Durant wrote (1951), mathematics had dominated philosophy in the XVII century, giving to the world Descartes, Hobbs, Spinoza, Leibnitz and Pascal. In the XVIII century psychology influenced philosophy, as noted in the writings of Berkeley, Hume, Condillac and Kant. In the XIX century the writings of Schelling, Spencer, Schopenhauer, Nietzsche and Bergson showed that biology was the background of philosophical thought.

The main impact on philosophy in the XX century came from physics. At first, it was quantum mechanics and relativity theory. Closer to the end of the century synergetics formed the central issues in ontological discourse. However, in all aspects of reality, evolution has been a prime issue of philosophical importance for a long period of time. Explicitly or implicitly, on the stage or behind the curtains, evolution was always a part of philosophical discourse.

Usually evolution (in the proper sense) is related to living organisms and technology. Such evolution has additional features, according to which we call it *discerning evolution*. Namely, discerning evolution goes through three stages that form a cycle:

1. Emergence (creation or production in technology) of new systems.
2. Evaluation, which goes usually in functioning of the system and is very often implicit.
3. Selection.

Usually it scientists pay much less attention to the second stage, forgetting that evaluation (even implicit) is a base and driving force for selection. However, even living organisms (such as plants and animals, not speaking about people) are evaluated by life. This evaluation determines which organisms will live and which will perish, which organisms will reproduce themselves and which will leave no descendants. In human society, the process of evaluation becomes more explicit and thus, more crucial. One of the multitude examples is the hiring process in academia.

However, Smolin (1999) introduces evolutionary thinking even into physics, suggesting that "the underlying structure of our world is to be found in the logic of (biological or discerning, M.B.) evolution." Today's physicists, he writes, have overturned Newton's view of the universe, yet they continue to cling to an understanding of reality not unlike Newton's own - as a clock, an intricate yet static mechanism. Smolin sees the very fabric of reality as changing and developing. "The laws of nature themselves," he argues, "like the biological species, may not be eternal categories, but rather the creations of natural processes occurring in time." A process of self organization like that of biological evolution shapes the universe, as it develops and eventually reproduces through black holes, each of which may result in a new big bang and a new universe. Natural selection may guide the appearance of the laws of physics, favoring those universes that best reproduce. Smolin's ideas are based on recent developments in cosmology, quantum theory, relativity and string theory, yet they offer, at the same time, a completely new view of how these developments may fit together to form a new theory of cosmology. The result will be a cosmology according to which the fact that the universe is a home to life will be seen to be a natural consequence of the fundamental principles on which it has been built. This will be in direct contrast with the older point of view, coming from Newtonian physics, according to which the fact that the universe contains life, or any form of organization, is accidental. We exist in a universe filled with an array of beautiful structures ranging from the molecular organization of living things upwards to the galaxies, and science must ultimately explain why. In so doing, science will give us a picture of the universe in which, as the author writes, "the occurrence of novelty, indeed the perpetual birth of novelty, can be understood."

Ideas of Smolin are related to the many-worlds theory (Everett, 1957; DeWitt and Graham, 1973; Davies, 1980; Herbert, 1987). Smolin (1999) claims that the ensemble of the universes may evolve not randomly but by some Darwinian selection, in favor of potentially complex universes.

Evolution in the proper sense implies existence of three pure types:

- *Progressive evolution*;
- *Regressive evolution*;
- *Oscillatory evolution*.

Progressive evolution of a system reflects development of some system parameter. For instance, if we take such parameter of humankind as the number of people on the

Earth, then evolution with respect to this parameter is progressive. Regressive evolution of a system reflects decline of a system parameter, while oscillatory evolution represents cycles (waves) in the process of changes.

As the scale of a property is not always a linear order, the type of evolution can be undefined because the values of the measured parameter are not ordered. Besides, there are situations when it is impossible to measure these values to determine the type of evolution. For example, it is a question whether on the contemporary stage of human evolution, people are becoming more intelligent or only more knowledgeable.

In addition, considering a complex multiaspect system, we encounter a situation when it is progress by one criterion and regress or oscillation by another. This shows that in many cases evolution often has a mixed type when one parameter is increasing, while another parameter is decreasing.

Any system R is represented by a set $\mathbf{Q} = (Q_i; i \in I)$ of aspects or features Q_i. In the mathematical setting, these features/aspects are modeled by abstract/real properties P_i .

Definition 9. A representation $\mathbf{Q} = (Q_i; i \in I)$ is called a *systemic stratification* when each aspect/feature Q_i is a state of some subsystem R_i of R. in this case, an aspect Q_i is modeled by the state vector P_i of this subsystem R_i.

Theorem 3. *Systemic stratification of a subsystem in a systemic stratification induces a systemic stratification of the whole system*.

Any change of change of R_i is, at the same time, a change of system R. Consequently, each aspect Q_i determines an *aspect inner time* T_i in R. This time is isomorphic to the system time of R_i in the case of a systemic stratification. Theorem 3 implies the following result.

Corollary 1. In the case of a systemic stratification, an aspect inner time T_i in a subsystem Q of a system R is an aspect inner time T_i in R.

Sometimes dynamics of a system R is represented by behavior of some aspects/properties of this system. Namely, there is a system $\mathbf{Z} = \{ P_i; i \in I\}$ of properties P_i such that any change of R results in a change of some P_i from $\mathbf{Z}$. Results from (Burgin, 1990a), there is a property P which is equivalent to the system $\mathbf{Z}$. In particular, any change of R results in a change of the property P. As a consequence of Theorem 2, we have the following result.

Corollary 2. If dynamics of a system *R* is represented by behavior of some collection of aspects/properties of this system, then time in *R* has an ontological base.

Studying and modeling evolution of a complex system *R*, it is efficient to consider not evolution in general but evolution of different aspects/features of *R*. Awareness of such aspect evolution leads to better understanding evolution of the whole system. This is an application of the traditional scientific approach based on the analysis-synthesis cycle, which originated in ancient Greece and is a powerful tool of modern science.

With respect to progressive evolution, the following principle reflects its main feature (Burgin and Simon, 2001).

Enrichment Principle (**EP**). Evolution is a hierarchical process that increases in complexity over time.

As an example, let us look at the evolution of elements. Starting with the basic elements that form in young stars such as our Sun, we may note that the simplest element, hydrogen, is converted into helium, a somewhat more complex element. It is the first step of element evolution and it takes the immense amount of heat that is generated in the interior of a star to bring about that transformation. For example, what we see on the surface of the Sun are storms produced by this action. What happens inside the star is that from time to time a pair of nuclei of heavy hydrogen collides and fuses to make a nucleus of helium. As a matter of fact, helium was first identified by a spectrum line during the eclipse of the Sun in 1968. At that time such an element was unknown on earth. That is why it was called helium.

In time any star and our Sun grows older and become mostly helium. At the same time it becomes hotter and hotter. It involves collision of many helium nuclei. Heavier atoms result from these collisions. Among them are such elements as oxygen, silicon, sulfur, mercury, carbon, etc. Since those elements are composed of subatomic particles (electrons, protons, neutrons), we can readily see that there is a hierarchy of complexity within the stars themselves.

McShea (1996), who has studied different components of living organisms, has collected a great deal of scientific data in support of EP. For example, complexity of cells has gone immensely up in the last four billion years.

Enrichment Principle implies that evolutionary thinking is based on an unbounded model of time contrary to a cyclic model inherent stationary thinking. Thus, a cyclic model of time prevalent in ancient societies (Kosareva, 1988) excludes evolution. As it is written in Ecclesiastes, "That which hath been is that which shall be."

In contrast to this, evolutionary thinking demands unbounded time in the mental model of the corresponding system. As a result, evolution in a general sense is equivalent to unboundedness of time, while evolution in the proper sense demands in addition unboundedness of the domain of the system trajectory in the state space.

The concept of an ontological base P of time T (cf. Definition 7) allows us to introduce rigorously the concept of evolutionary time. Let $\mathbf{P} = \{ P_i; i \in I\}$ be a system of properties of a system R with respect to which evolution of the system R is considered. It is possible to represent the system **P** by one property P of **P** (Burgin, 1990a).

Definition 10. Time in R for which P is the ontological base is called an *evolutionary time* of R.

As Boberg (1993) writes, evolutionary time of the Darwinian theory of evolution is linear. In her version of the theory of evolution, Boberg introduces reciprocal time.

Considering additional properties of the system under consideration, it is possible to come to an essentially different evolutionary time. For instance, the conjecture that evolution of species goes in branching time is more plausible. In this model, different temporal branches correspond to different species, which evolve in their own time.

5. Conclusion

To conclude, let us consider a painful problem related to controversy between scientific and religious thought on the issue of evolution. Some contradict evolution and existence of God, believing that the evolutionary process in biology gives an argument that disproves religious assumptions that God created the world. In reality, our knowledge about such processes invalidates only primitive understanding of world's emergence. This understanding was developed by people who lived millennia ago and had much lower level of knowledge. Many of our contemporaries think that faith contradicts science. However, even several hundreds years ago, such great scientists and philosophers as Newton and Leibniz demonstrated that it is possible to eliminate many contradictions and to achieve a relative consistency between religious and scientific world perspectives, which to other more ordinary people seemed absolutely irremovable.

The main controversy that involves evolution is the opposition of evolution and creation of species. In this case, creation is considered as an ultimate action after which nothing is essentially changing. At the same time, evolution implies development and emergence. To solve this dilemma, we can apply the saying of Buddha that extremities are bad and the truth is in the middle. This brings us to the concept of evolutionary creation, in which creation is performed by long-term process. This concept synthesizes both classical evolutionary and creationist approaches in a similar way as modern quantum mechanics have synthesized the concepts of a particle and wave, demonstrating that light, elementary particles and some other physical phenomena have at the same time properties of waves and particles. A new development of this approach brought physicists to the models of vibrating strings and branes.

To be honest, it is necessary to admit that now people in general and science, in particular, have insufficient material evidence to make a final solution which theory is correct. Moreover, some theoretical results show that rational cognition based on proved evidence is always bounded. For instance, in the algorithmic theory of information and probability (cf., for example, (Chaitin, 1977; Vyugin, 1981)), it is proved that it is impossible to discern algorithmic and random sequences of events.

Moreover, randomness of a process is not absolute, but depends on our cognitive algorithms that bring us knowledge about this process. Thus, what can look as a random process for one observer, can be regularity for another one.

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