NeoPlexus – developing a heterogeneous computer architecture suitable for extreme complex systems

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Abstract—**NeoPlexus is a newly established permanent program of international collaborative scientific research and application development. It is focused upon the design, construction and application of a new architecture and family of computing machines that are adept at solving problems of control involving extreme complex systems (XCS) for which conventional numerical computing methods and machines are fundamentally inadequate. The GCM involves a different foundation of computing from classical Turing Machines including qubit-based quantum computers and it incorporates geometrical and specifically topological dynamics. The target for implementation is to construct molecular-scale platform using protein-polymer conjugates and MEMS-type microfluidics.**

Keywords—computing architecture, complex system, quantum computer, molecular electronics, consortium, collaboration.

I. Introduction

NeoPlexus is a program of scientific research and application development that has evolved out of a recognized need for a new type of computing architecture. It is focused upon the design, construction and application of a new architecture and family of computing machines that are adept at solving problems involving extreme complex systems (XCS) for which conventional numerical computing methods and machines are fundamentally inadequate. As a program it is unique in several respects, notably the emphasis upon long-term sustained application development, commercialization and economic self-sustainability concurrent with basic research that spans several areas of specialization.

Such extreme systems, of both natural and human-engineered origins, have attributes of high uncertainty, noise, non-linearity and unpredictability. Use of conventional mathematical and computational models based upon formal, deterministic approaches including empirical observations and experiments, and the derivation of numerical-intensive algorithms including the vast majority of rule-based, pattern-learning and other formal artificial intelligence methods, have limited and uncertain reliability for control as such XCS increase in their state-space variability and as demands increase for adaptive, non-linearly responsive and computationally fast cybernetic techniques. These XCS may be characterized as non-deterministic, non-algorithmic and computationally NP-hard, regardless of instances where the control of such systems can be approximated for average or even majority cases.

The rationale for Neoplexus is the need to provide accurate, reliable and practical modeling and solutions for many challenging tasks involving XCS among both natural and human-engineered systems. Some of these are constant and chronic challenges that are not new but such that the complexities, difficulties and the problems with current-technology approaches are now demanding more reliable and efficient solutions. Some of these problems are emergent and relatively new due to changes in natural environment, society, and lifestyle. They range in topics from agriculture to finance to medicine to space and other fields of industry, economics, and society. Critical and time-sensitive solutions to many such XCS extend beyond the capabilities of conventional computing and algorithms including cognitive technologies such as artificial intelligence and machine learning. Derivation of solution sets for these XCS constitute omnipresent and persistent problems within virtually every aspect of human life, affecting social organization, economy, energy, health, and technologies upon which the vast majority of global socioeconomics is dependent.

The demand for the architecture, machines, algorithms and other technology provided by NeoPlexus is vast and open-ended but particularly strong in certain critical areas of human society and economics, particularly in five areas:

[1] agricultural and environmental modeling, planning and management

[2] biomedical and pharmaceutical research, clinical trials and population studies

[3] energy production, distribution and optimization, including new sources such as nuclear fusion

[4] space industrialization and commercialization including planetary monitoring and asteroid defense

[5] population-based social monitoring and predictive trend and disposition analysis

Within each of these five broad domains are particular mega-challenge problems that are literally “make or break” problems for human culture at both national and global levels. The development of new, reliable, and economically practical computational technology is an imperative.

NeoPlexus exists as a unique program to define, create, build and cultivate this new technology using a different model for how modern research and development has typically been sustained – piecemeal, short-term, and with limited, even over-specialized “focal length.” It has been designed as a program spanning the necessary scope of research coupled with applications for both testing and proving the utility and correctness of the new computing architecture and creating a sustainable channel for introduction of the new machines into mainstream markets and social use on a widespread scale. The program integrates basic research with clear application objectives, milestones, standards of measuring success and utility, and methods of achieving social receptivity. It is unique as a program that is open-ended and permanent, with an economic management plan for internal growth and sustainability that includes a formal endowment fund, intellectual property and technology transfer management, and well-defined methods for commercialization revenue including securities-based capitalization returns.

II. Architectural Basis

The scientific basis and technical target of NeoPlexus is a new computing architecture that is known as the Generalized Computing Machine (GCM). The GCM involves a different foundation of computing that incorporates geometrical and specifically topological dynamics, employing a physical principle known as topological information resonance (TIR) [1]. The scientific basis for TIR is grounded in well-established quantum mechanics, quantum biology, condensed matter physics and cellular biology [2,3]. The theoretical foundations for TIR leading to its development as a computing model and engineering implementation incorporate new theoretical interpretations and experimental findings within physics and the biological sciences that are consistent with and supportive of new models of quantum behavior in such areas as Planck-scale fundamental physics, particle and nuclear physics, Bose-Einstein condensates, superconductivity, and macromolecular communications and signaling involving proteins and nucleic acids within living systems. Thus, the foundations and the implications of what provides the basis for TIR and the GCM are closely coupled with informational and cybernetic models spanning elementary physics, biology and information science.

The GCM is not solely a new machine using the distinctive TIR process. The computational model of GCM is strongly heterogeneous and involves discrete physical processing elements which perform the TIR operations in conjunction with conventional computing systems that provide numerical processing and the channels of input and output to the external world. Thus, NeoPlexus is a heterogeneous parallel processing system that has a unique and essential component, the GCM, which implements a radically different form of computation than that in all conventional computers of the past and present (including current-research-focus “quantum computers”), and this innovation is TIR, a topologically based method that involves the dynamic real-time modulation and change of molecular-scale structures. But along with the “trans-Turing” process of TIR is the use of diverse digital “Turing machine” computation, particularly in the process of translation and transmission of information between the GCM machine(s) and the external world of conventional computers, robots, and humans. Ultimately, in the world of applications, the computing that derives from NeoPlexus will be integrated into control systems for diverse embedded use, especially involving cooperative robots, servo-mechanisms, sensors, actuators and other devices that are themselves acting as adaptive, intelligent agents in an XCS environment.

The engineering technology for NeoPlexus and its GCM involves submicron-scale integrated circuits that are composed of macromolecular structure assemblies. These base units, analogous to the integrated circuits (IC) comprising contemporary industrial semiconductor electronics and also new nanoscale circuits (e.g., qubit arrays built of quantum dots and comparable micro/nano structures), incorporate proteins and other polymers with nano-scalar additive components including metallized conductors and semiconductor elements. These are described as a molecular electronic bioinformatics circuit (MEBIC) [4]. Such units function in manners similar to certain intracellular structures within different components of higher-order biological cells (“eukaryotic” type, with nuclei) and in the comparatively simpler architectures of bacteria and certain viruses. Thus the topological computing processor (TCP) elements implement a form of synthetic biology but in the form of structured arrays and networks of macromolecules arranged in a particular geometry, as opposed to a living cell, natural or genetically-modified.

Internally, the mechanics within the TCP elements employ a principle which can be termed coherent quantum entanglement resonance (CQER). This involves quantum entanglement that can occur through dynamics structures in the molecular network of the TCP but not at all in the same fashion as in qubit-based devices that aim to create and sustain entangled states among specific elements (the qubits). CQER is an open goal of the theoretical work ahead. This process is used to represent and transform models, comprised of parameters and functional relationships of such parameters, that correspond to the external complex and non-deterministic systems. Such models, represented and manipulated in the medium of 3D macromolecular arrays, change in their topology and thus in their representation of information that is mapped from and later mapped to the external systems that are the subject of the computational work being done in the GCM.

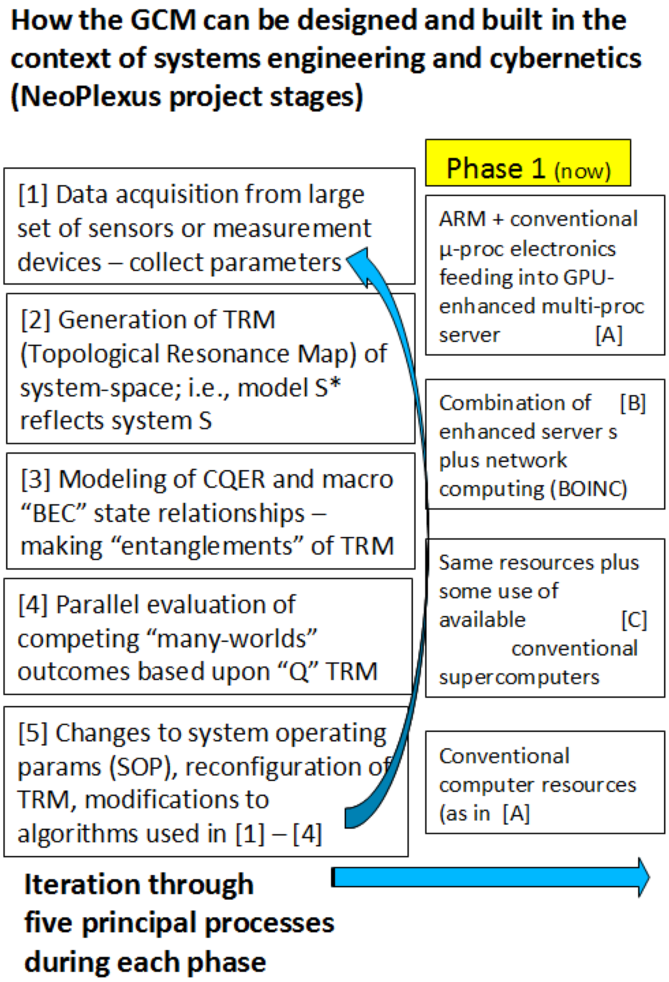

Fig. 1 (a) Four phases of development of GCM within NeoPlexus (see Fig. 1 (b))

Communications among TCP units as members of a processing network, between TCP units (as individual components and collective multi-unit assembly) and external non-GCM components of the computing architecture (e.g., standard digital CPU, DSP, GPU, memory subsystems) is engineered through nanoscalar substrates incorporating graphene and other hybrid elements for communication.

The GCM and its TCP incorporates internal topological processing that involves the physics of quantum entanglement for information representation and transformation. However, the physics and engineering involved is distinctively different from many recent and current research endeavors colloquially known as "quantum computing." Such machines are based upon architectures that are still fundamentally derived from the same "Turing machine" model. The latter defines all conventional computers that are engineered to execute finite sets of instructions which perform discrete actions (exact, static, unchanging binary logic or otherwise as in the "qubit" logics of "quantum" Turing machines) [5,6]. TIR processing, and the TCP which constitutes the GCM, is based upon a paradigm relatively new to computer science and information technology but not to quantum physics, molecular biology or neuroscience. Among examples in biology providing a basis for TIR are the studies of cellular membrane control of ion channels [7], biosolitons [8], and the microtubulin assemblies of the cytoskeleton in eukaryotic cells [9, 10,11,12].

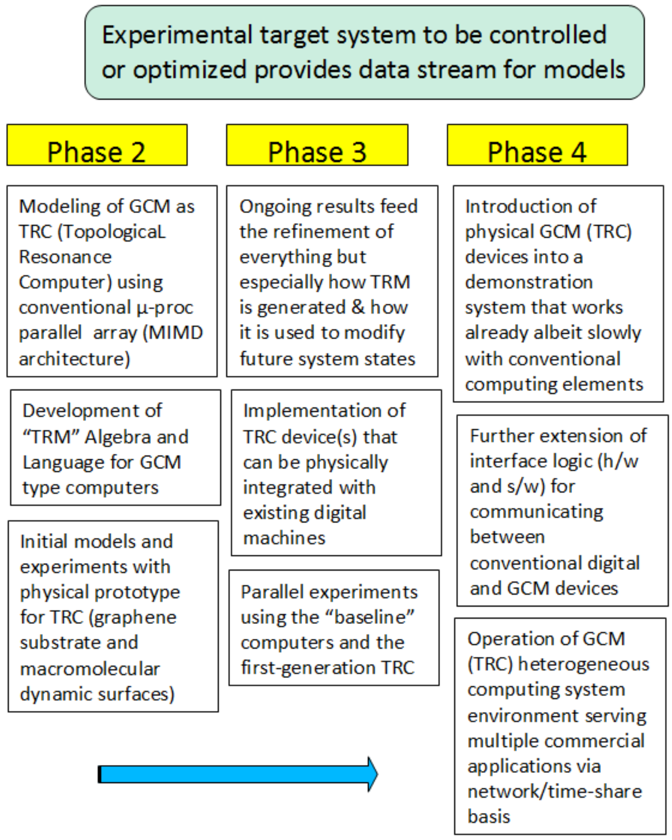

Fig. 1 (b) Four phases of development of GCM within NeoPlexus (see Fig. 1 (a), preceding page)

This differentiator is absolutely significant for understanding how and why the NeoPlexus machine and its derivatives will be able to solve classes of problems that no other computer before – nor any computer based upon the Turing model of computation exclusively - can adequately or reliably solve. These are problems where the mapping of a particular model to the complete system may change in a nonlinear way but where changes in a topological representation of the system state-space or portions thereof can indicate transitions in future states. It is not that the GCM will be faster at numeric calculations, nor that it will perform certain steps (e.g., factoring) in a quasi-parallelism that is based upon a superposition state of a register of bits in a physical entanglement state. Rather, it is representing and manipulating information differently by translating features of a state-space into topological operations that can be reflected in the actual geometry of molecular arrays.

III. Programmatic Basis

NeoPlexus as a program is intended to be a permanent and self-sustaining institution, an entity and activity with cohesive organizational and functional structure in virtual perpetuity, unlike most other research projects whose periods of planned duration, execution, and sustenance are short-term (generally 1, 2 or at most 4 years). There are three principle reasons for the different approach taken with NeoPlexus. One pertains to the science and technology that must be discovered and constructed, including within theory. One is technical and economical. The third is social and educational.

First, the nature of the core problems within all aspects of the NeoPlexus science and engineering is such that specific time constraints cannot be placed upon the required research, experimentation and application tasks. Discovery and provability can be pushed, accelerated but not scheduled in advance. Achievable goals including demonstrable and even commercially-viable systems can and will be established, with generally 3 – 5 year timetables. Iterative application building and testing is an essential and concomitant (necessarily concurrent) part of the process. An architecture must be designed that is theoretically sound and simulatable and physically feasible with electromechanical and software components. These must become practical and acceptably integrated within the mainstream computing and control world. This will take time and there will be variants, tributaries, and derivatives unable to predict or plan all ahead.

It is essential to have stability in the team of persons, resources and facilities, that for all participants and interest groups, there will be consistency and a reliable continuum without the typical breaks and shifts that arise in many projects of decidedly finite focus and duration. The program must provide an environment of consistent and reliable presence for all participating elements, including all permanent and collaborative personnel and resources both tangible (e.g., machines, instruments, laboratories) and intangible (e.g., models, software programs, and the general atmosphere of focused engagement upon the project tasks).

Secondly, the entire application space, the set of implementations, the use-cases to which the NeoPlexus computing machines will be directed, both for continuous experiment, testing and refinement, and for introduction into commercial, industrial uses, demands that applications not be limited to businesses and companies but include public-sector (governmental), educational and human service uses. This is product-like commercialization and industrialization, in this case the GCM machines that will be produced as a result of the NeoPlexus technology transfer to some production company. As a general rule, each such application, by virtue of being inherently a kind of XCS, has an order of complexity that does not lend itself to singular, well-definable, clear-cut, and "easy" development. This is within the very nature and essence of what is an extreme complex system (XCS).

There is an inherent expectation of going through different iterations and interpolations within the application development process. This is a bi-directional process as well, meaning that as the application of GCM and the fruits of NeoPlexus are applied to some particular system problem – for example, within cooperative multi-agent robotics in agriculture, manufacturing or space-based engineering, or within tasks of pharmaceutical drug design and predictive healthcare outcome analysis, or within predictive modeling of large population trends of expectation and reaction in socioeconomic analytics – there will be design feedback from the *application-space* to the *machine design-space*. Changes will be expected, even significant ones, affecting the architecture of the NeoPlexus components, conceivably affecting very fundamental engineering components such as the TCP and the internal models for performing and analyzing the TIR events, as a result of early application simulations and experiments.

The nature of XCS and the GCM as a solution-engine for intelligent control of XCS is such that an evolutionary full-feedback-loop environment must be expected and provisioned for in the NeoPlexus program; it must allow for an open-ended lifecycle, one that can be sustained with the necessary resources (and thus the capital for those resources) that will enable a consistent continuum of focused uninterrupted work. This is a distinctive difference between NeoPlexus and most other research and development projects. However, the very nature of the program and its work provides an excellent solution to the challenges of maintaining stability including sustainability of capital for the program's requirements. The heart of this solution is not to be found in reliance upon fluctuating grants and awards from different agencies (public or private), nor in conventional-modeled venture capital investment practices, most of which do not provide for the long-term or open-ended nature of programs like NeoPlexus.

A third and very important reason for NeoPlexus being a permanent and even formally endowed program is for social reasons, and the need to build a sustainable educational platform extending to the population of future users of such trans-Turing machines. This is comparable to the transitions and growing-pains experienced in the mid-20th century with the introduction of elementary transistors and integrated circuits. Semiconductor tech followed Moore's Law into submicron scales, leading to MEMS fabrication, but there were major gaps in the educational sector. Gradually and systematically these were addressed but not without "gap" periods with shortages of scientific and engineering specialists and deficits in general education of users and operators. There may be even a steeper "adaptation curve" in transition from purely digital electronics into one that incorporates both biomolecular technologies and a new model for what we mean by the process of computation.

This also pertains to the broader user-space of where such devices can be applied. Only some fifty years ago, the notion of the personal computer, much less a palm-sized device, capable of what we have in the simplest Android phone of today, was considered to be “science fiction.” The “internet of things” first accrued visibility and credence in the domain of household appliances and SCADA control systems. Possible new classes of devices combining pattern recognition, adaptive learning, and speed, usable in wider sets of applications, including such consumer-level biomedical implants and therapeutics, creates a demand for education and communication-outreach for the general population. Building such resources and tools requires (as does the R&D), a stable core, both as a team and as an organization. Consider how much has been accomplished in high-energy particle physics and now imagine there not being CERN, DESI, or FermiLab. With NeoPlexus there is no requirement for vast size, facility, infrastructure or capital resources, but the nature of the GCM requires more than the typical NSF or Horizon 2020 structure.

Within NeoPlexus as a consortium the educational efforts are led by a consortium member, MIRNOVA Academy [13]. The focus is on two groups and projects: (1) students and young adults (principally high school and university-level), with special team-oriented projects, and (2) training of teachers and mentors for such projects and as more generic “continuing education.” These activities are all designed to link participants directly with practical applications and are explicitly linked with internship and apprenticeship activities in both academic and corporate environments. The goal is to build an awareness base for both paradigm-shifting technology as TIR and the GCM and for applications realistically addressable by the new computing architectures. Prime attention is in agriculture, space, cooperative robotics [14, 15].

In Fig. 2 are shown four general problem areas not sufficiently addressable by conventional modeling and computing, and four task areas that the NeoPlexus machine and program can answer at multiple levels including commercially and educationally. The argument here is that these must all proceed in sync together in order to succeed. Partial, step-wise and insecure project efforts can succeed incrementally but the wholistic and systemic nature of the work requires the long-term thinking that is in NeoPlexus. As a historical reference, classic Gothic cathedrals were all built incrementally, stone by stone, but only with a comprehensive unified plan and a commitment to construct the edifice.

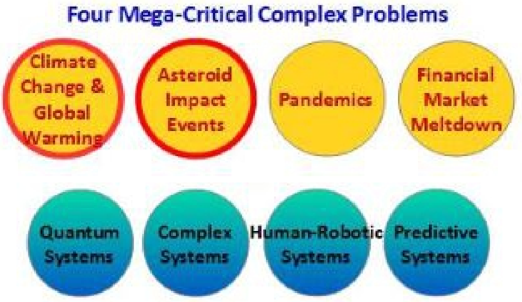

Fig.2 Four generic unavoidable mega-problems and the need for a four-fold solutions approach

IV. Directions Forward

NeoPlexus is in a beginning-stage and this includes the consortium of participants, as individuals, institutions, partners and sponsors. This paper is itself a “first-page forward” statement and there will certainly be more details and developments by the time of this paper's publication. Here a few statements can be made in summary about what is taking place and will be activities in 2018 and future years.

GCM = a Generalized Computing Machine. Trans-Turing. Incorporating 3d topological representations of state-spaces, using morphological changes to represent changes in those spaces and then translating the information into forms usable by digital (numerical) machines.

Key Attributes (Characteristics) of the GCM:

I. parallel, distributed, heterogeneous, hybrid computing

II. functions of pattern recognition, pattern-fitting, mapping of ill-defined, unstable and hard-to-isolate parameter sets, stochastic and randomized sampling and estimating, functional similarity and congruency mapping between sample sets and system models

III. CSP (communicating sequential processes) and process algebras, evolving into CDP (communicating dynamic processes) with dynamic channels and data protocols, MIMD-type parallelism

IV. incorporating SPSA and randomized local neighborhood (cellular automata cluster) sampling

V. employing principles of quantum entanglement and quantum logic but distinctively and physically not the same as so-called quantum computing focused upon Shor/Grover-type factoring and sorting algorithms

VI. incorporating elements of biological neural networks but distinctively different from contemporary neural-network algorithms and devices

VII. behaviors and implemented devices exhibiting and employing: resonance, set-theoretic models, Bose-Einstein condensates, quantum entanglement using noise from “superposition-collapse” as information, not as “noise”

VIII. biologically-inspired, likely to involve biomolecular components, (e.g., protein-polymer conjugates), capable of operating at “room temperatures” and not requiring special, extraordinary cryogenic operating environments

IX. integrable with semiconductor-based “Turing Machine” (TM) computers through some bridge-tech

X. applications focused upon control, optimization, stabilization, and decisions based upon uncertain and fluctuating outcome possibilities (e.g.,business data mining, predictive analytics, game-theoretic processes, forecasts, large-population dynamical predictions.

Key Areas (Tasks) of Research Ahead

Theoretical Foundations

- Consolidating and rigorously defining the formal, mathematico-logical representation and differentiation (e.g., from TM formalism) of what operations constitute a GCM.

- Building and stabilizing a type of process algebra that can be used to describe a GCM and then be "translated" (interpreted) formally into a language that defines algorithms and ultimately from such high-level formalism into "software" (but "software" for the GCM is by "first principles" something quite different from TM software languages).
- Mapping such process algebra into a process language that describes 3d conformational changes in a network that can be constructed and maintained using molecular building-blocks ()e.g., nano-doped proteins where metallized nanoparticles act as quantum dots – but not, it should be noted, as qubits but as switches).

Algorithm Descriptions

- Defining the limits – how a GCM is different from an "instruction set" (e.g., for a TM or a TM_{CQC}).
- "Taxonomy" of algorithm classes and types – for instance, a generalized model of randomized algorithms using stochastic sampling, scalable (fractalizable?) cellular automata networks, adaptive neural networks, self-modifying clusters, etc.
- Scalable to many-body problems and not only in micro physics and chemistry but in socioeconomics.

Functional Definitions

Approaching a type of "lambda calculus" for GCM. A set-theoretic, process-algebra method of defining operations that may be simple or composite tasks performed by a GCM (which, remember, is a parallel distributed and heterogenous architecture that may have may different "processors."

Model Definitions

This concerns the "mapping problem" that seems to be at the essence of the GCM. Taking a "black box" system S which is either intractable or indeterminate about being computable in any polynomial time or even reasonable NP time, for understanding how it operates and how to predict and control its future, and mapping that into some model m_i that can be manipulated and "controlled" but in such a manner as to be able to effect actions in S on the basis of operations (computations performed on) m_i. or alternatively a different model constructed real-time on the basis of the changes in m_i.

"Programming" Environment

The thinking here is for building a toolset similar to the design environments used in semiconductor design (e.g., Cadence, Mentor Graphics, Synopsis) and CAD (e.g., AutoDesk product lines), rather than programming tools such as are used in C, C++, Java, etc. Some of the initial knowledge-based "AI" tools (e.g., Symbolics, Lisp Machines) and parallel languages such as OCCAM come remarkably close to the intended goals.

Applications Environment

This entails building middleware and "API" functionality. There will be issues of "hardware" and especially challenging, perhaps, if this involves materials and machine components that outside of basic "transistor-->IC" electronics. This environment must adapt to and serve many use-cases. It will be well for it to be developed within the educational project world such as is being done by MIRNOVA Academy.

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