Exploring the Biological Metaphor in Evolving Complex Cyber – Physical Systems

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Abstract **- "Expecting the Unexpected" is a vital facet of "Systems Thinking" that facilitates structural, not event-level solutions amidst conflicting demands and daunting constraints. Systems enable the understanding of how strategies work and why. In challenging times, it is crucial to remember, and practice the unique strengths of systems thinking and organizational learning. Today computational paradigms and metaphors have permeated virtually every walk of human endeavour.**

A method to expect the unexpected in a systemic manner is "Human-in-the-loop [HITL]". HITL is a branch of artificial intelligence that leverages both human and machine intelligence to create machine learning models. People are involved to validate a machine learning model's predictions as right or wrong at the time of training.

The use of biometrics has been successfully applied to security applications for some time. Biometric technologies are predominantly used to authenticate individuals in applications such as access control to specified resources, image processing and marking routine attendance. Biometrics attempts to automate the recognition of behavioural and physiological characteristics of an individual. Individuals provide certain personal characteristics to the sensors. The Human-Biometric Sensor Interaction [HBSI] is a conceptual model to study several concerns in usability related matters.

"Behavioural Biometrics" and "Morphological Biometrics" further advances in this type of applications. "Behavioural Biometrics" is related to the measure of unique and measurable patterns in human activities. It is more aligned to the social facet of the human being. "Morphological Biometrics" study the biological facets of human beings.

"Humanistic Intelligence [HI]" arises because of a human being in the feedback loop of a complex system, where the human and computer are inextricably intertwined. Wearable Computing Technologies and a wide range of implants have the potential to match the biological brain.

This paper is a study of the biological metaphor of evolving complex Cyber – Physical Systems.

1. Introduction

The century of complexity has begun. The evolving complexity that is interdisciplinary and has potential for both paradox and non-linearity banks on "Systems – Theory and Practice" to get to the other side. There are three dominant types of systems across the organizations. They are repetitive, adaptive and innovative systems. These systems determine the way the workforce gets aligned and learns.

Systems thinking represents a way of solving complex problems that fall outside well established disciplines. The challenges ahead include working with:

- Geographic Metaphor
- Computational Metaphor
- Biological Metaphor
- Epistemological Metaphor
- Anthropological Metaphor
- Sociological Metaphor
- System of Systems Metaphor

There are a few transformational theories spanning across several metaphors indicated above. The quest for General Systems Theory, Cybernetics and Adaptive Control Systems has

produced many ideas and eminent researchers with pioneering achievements.

Some of the areas in which systems thinking has proven its value include:

- Complex problems that involve helping many stakeholders see the “big picture” and not just their part of it
- Problems where dependence on past actions of others dominates
- Problems where the context has several interacting sub-systems that are heterogeneous
- Problems whose solutions are not obvious when studied in isolation

Human being is considered on the basis of two different dimensions of existence namely the biological and the social. Human beings happened on earth as a result of a long process of development. It is established that as biological organisms, they still retain a close genetic connection with the animal world. Man's organism has many features in common with the higher animals. Human beings are the pinnacle of a great biological system, the latest to emerge on historic timeline of evolution, and the most complex of all known organisms. Human being is an integration the biological i.e. the organismic and the personal i.e. the natural and the social, the inherited and what is acquired during a lifetime. Thus the biological factors should not be reduced to the genetic.

1.1 Biology

Well engineered control systems thrive on negative feedback. Biology on the contrary thrives of positive feedback. Thus any model based on biology is innately difficult to integrate with the prevalent feedback control systems. However, the biological metaphor involving Human-in-the-Loop holds the promise of steering to safety in quick time. Biology as a series of engineering problems with natural solutions appears to be a viable computational system using the biological metaphor. Please see the Figure 1 to draw an analogy.

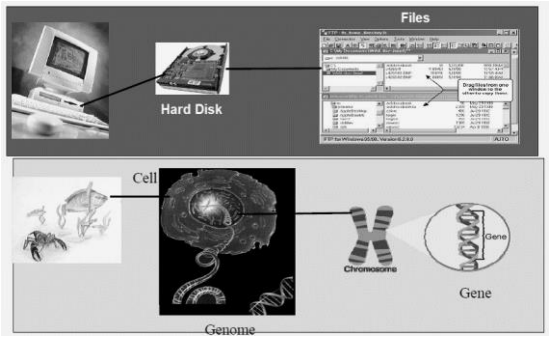

Figure 1. Operational similarity of a Computing System and Biological System

1.1.1 Biological Person

Any number of biological facts do not show the person as others perceive and think. This remains a core concern in using biometrics. It is widely known that any complex organism revealed by the usual observational methods of the biologists is distressingly incomplete. There is no observable or postulated biological property that automatically or by some logical necessity entails the rights of personhood.

Since at least the time of Aristotle, philosophers have debated what it is that constitutes an individual person or thing. What makes it a unity, numerically one? What distinguishes it from everything else?

An individual thing as a concept is clear and tends to be highly intuitive. An individual is something of a specific kind that is a unity having its own identity. In principle, it is always intuitively possible to discern it from any other individual even within the similar kind. Formal analysis of this principle poses a cluster of problems that are difficult to solve with the standard framework of

mathematical logic and the contexts of its effectiveness.

1.1.2 Individualism

Individualism is the first step towards the social human. It reflects the quality of being an individual i.e. individuality in possessing. It can also be an individual characteristic or even a quirk. Individualism is also associated with artistic interests and lifestyles where there is a tendency to make perceptible departures from the popular mass opinions and behaviours.

1.1.3 Individuation

Individuation is related to the metaphysical problems of constitution, composition, colocation, essentialism, and identity. The process of individuation is to become inwardly whole, discovering one's self beyond the ego states. It defines the essence of the human. Individuation entails the following concepts.

1. Symbols – imaginative, external and internal.
2. Consciousness and Paradoxes
3. Archetypes.
4. Complexes
5. Projections
6. Shadow
7. Anima [beauty, desire, mystery] & Animus [rationality, judgement, intellect]
8. The Metaphysical Human
9. Authenticity

"I have always said to my pupils: Learn as much as you can about symbolism; then forget it when you are analysing a dream."

Carl G. Jung

Human-in-the-Loop is thus a tough challenge in the evolving complex Cyber – Physical Systems from the standpoint of Biology. Individuation for the purposes of Cyber – Physical Systems may be another quest for a mathematical description of physical systems.

2. Biology and Physics

All physical processes are driven by the principles of physics. When these processes are applied to living systems, the realms of physics and biology merge to define how organisms function, from the simplest forms of life to the most complex. The internal mechanisms involve and invoke the widest possible spectrum of disciplines of science and mathematics.

"Measure what is measurable, and make measurable what is not."

Galileo Galilei

Even in the mid 20thcentury, most people thought proteins were the molecules of heredity. In just under 60 years, biology has been completely rewritten. The ability to read and write DNA has completely changed the face of biology. It has, in a sense, created a new domain of life. The science of physics has become an integral part in our understanding of this new domain.

The science of physics deals with the interrelationships between space, time, matter and energy. Biology of the 20th and 21st centuries deals with these same concepts on the molecular and cellular scale.

There are several principles of physics that relate to biology. Some such well established relationships are given below.

- Lattice and Nuclei
- Pattern Formation and Morphogenesis
- Flow and Spatial Patterning of Gene Expressions
- Magnetic Field Theory

In 1952, Alan Turing formulated a type of "Mathematical Biology" to model the chemical basis of morphogenesis. Theoretical Biology has produced useful results in making biology meet physics.

Biological systems reach hierarchical complexity that has no comparison outside the realms of biology. However, the biological entities abide by certain fundamental physical laws the science of physics deals with the interrelationships between space, time, matter and energy. It is a challenge to specify a framework based on physics to understand the complexity of biological evolution. The complexity stems both from the evolving structures of the organisms and the rapidly increasing interactions between the cells.

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“Molecular and cellular biology have become more amenable to a research paradigm that melds experimental and theoretical investigations, and, more specifically, research that is geared toward an accurate description of how things move in space and time. It is, therefore, not surprising that physicists would be attracted to cell biological research.” - Charles Wolgemuth, Professor, University of Arizona, US

The cell is the “common denominator” in our understanding of life. The physics related to the motion of a single protein in a cell is very different (and much slower) than that protein’s motion in, for example, water. Many bacterial systems rely on dynamic “genetic circuits” to control critical processes. A major goal of systems biology is to understand these behaviours in terms of individual genes and their interactions. “Gene circuits” involve specific interactions between genes and proteins.

What are the principles of these genetic chemical circuits that operate inside cells? The real challenge is that unlike the static electric circuits designed based on known components, the genetic chemical circuits change rapidly. Also, the genetic chemical circuits are inherently noisy. Even noise can be used effectively to control the circuit. They are subject to stochastic variations with random fluctuations and non-deterministic behaviour. More importantly, some of the interactions may be truly irrelevant.

Rather than trying to “deconstruct” complex systems, scientists today are instead looking at a model for a simple gene circuit - a “bottom-up” approach to get a quantitative understanding of the principles of gene circuit design. This is known as Synthetic Biology.

Cellular clocks work as “feedback loops” where proteins are produced and then go out of the nucleus into the cell. It takes them time to re-enter the nucleus, where they are able to regulate (turn off) their own expression, causing the concentration of those proteins to gradually decline until they can no longer turn themselves off; then they begin a new cycle. The negative feedback in the control systems becomes evident in this aspect of biological systems. Also, at times the biological system s are not only stochastic but also deterministic. The cycle time is termed as “oscillation”. Certain oscillations can happen by design. A formal circuit theory in biological systems is elusive. If such a theory happens, one can possibly tune the biology of the brain or the heart much like a radio is tuned.

"We decided that [by] writing new biological software and creating new species, we could create new species to

do what we want them to do, not what they evolved to do."

J. Craig Venter,

Lead for the first draft sequence of the human genome and assembler of the first team to transfect a cell with a synthetic chromosome.

"All great insights and discoveries are not only usually thought by several people at the same time, they must also be re-thought in that unique effort to truly say the same thing about the same thing."

Martin Heidegger, a German Philosopher

In biological terms, a human being, or human, is any member of the mammalian species Homo sapiens. However, human beings not only define themselves biologically and anatomically, but also in psychological, social, and spiritual terms.

3. Human – in – the – Loop [HITL] – The Biometric Approach

The HITL for Biometrics has evolved as shown in Figure 2.

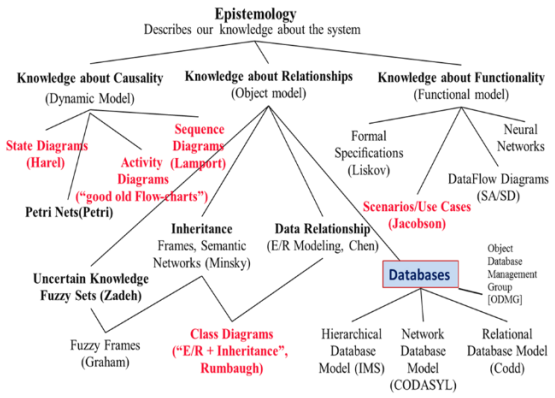

Figure 2. Evolution of HITL in the Biometric Approach

Structuralism and Objectification are the corner stones in this approach. The identity and diversity of individual objects may be grounded or ungrounded, and intrinsic or contextual.

Intrinsic individuation can be grounded in unique identification of the object or absolute discernibility. Contextual individuation can be grounded in relations, but this is compatible with absolute, relative or weak discernibility. Contextual individuation is compatible with the denial of unique identification, and this is more harmonious with science. Structuralism implies contextual individuation. In the context of mathematics all individuation is in general primitive. In physics contextual individuation may be grounded in relations with weak discernibility. In mathematics, an isomorphism is a structure-preserving mapping between two structures of the same type that can be reversed by an inverse mapping. Two different objects can be isomorphic i.e. have similar structures. It is not possible to identify objects in a structure except through the relations and functions that are defined on the structure in which the object has a place. In other words, only the objects permissible with the pre-specified relations and functions are deemed identifiable.

The Biometrics Technology was primarily used by the law enforcement. Presently, it is increasingly being used for verification of the Identity of a person. Biometrics is a method of recognizing or verifying a person's identity based on physical or behavioural characteristics. Every human being possesses certain unique features in terms of both physiological and behavioural characteristics that mark him / her as an individual. Anthropometry is the science of obtaining systematic measurements of the human body. It has been widely used for identification of individuals.

A Biometric Sensor is a device that converts the known biometric traits of any given individual into electronic signals. These devices are transducers

that model the human trait for the design and development of electronic circuits to identify individuals. However, the biological signals are not the same as the electronic signals. Biological signals, or biosignals, are space, time, or space-time records of a biological event such as a beating heart or a contracting muscle. The electrical, chemical, and mechanical activity that occurs during this biological event often produces signals that can be measured and analysed. Cybernetics is the science of communication and control to synergize the distinctive signals in machines and living organisms.

Biocybernetics is an abstract science and is a fundamental part of theoretical biology. Biocybernetics is the application of cybernetics to biological science for neurology and multicellular systems. Biocybernetics plays a major role in systems biology, seeking to integrate different degrees of information to appreciate how biological systems perform. Biocybernetics can be used identification, communication and control of Individual organisms within a biological system. It has been extensively used in medical and healthcare systems.

Bioelectrical signals are generated from the complex self-regulatory system and can be measured through changes in electrical potential across a cell or an organ. Anatomical parts of body and signalling methods include face, fingerprint, hands, eyes, ears, veins and voice while behavioural characteristics include handwritten signature, keystroke and gait. The limitations using the traditional biometrics include that they are unique identifiers that are not confidential and secure to any given individual. Using bioelectrical signals as biometrics offers several advantages to an identity management system. Besides their uniqueness, the bioelectrical signals are confidential and secure to an individual.

4.The Impact of Biology on CPS

Software engineers need to be technocrats both as individuals and as team members through vision and ingenuity. The Software Industry is recognizing that a healthy employee work/family-life balance is essential for long-term enthusiasm and success. It is clear that a strong architectural plan with input from all stakeholders creates a vastly different, participative and delivery working environment. The continued commitment to creating excellence and an atmosphere that embraces change are foundational characteristics of the Software Industry in future.

Treating people like they're human beings instead of hours to extract value from is an old fashioned concept that's coming back into fashion. Software Engineers have the greatest degree of variance in the level of their productivity. In the past 10 years, the scale of relative "valuable-ness" of otherwise-similarly-skilled-employees has grown quite a bit wider. Also, it's cheaper to humanize and retain software professionals over a long term. Humanizing entails Safety and Security, Human Relationships and Personal Growth. This is proving to be an answer to the productivity paradox in Software Engineering.

This paper is a study on HITL for blending technocracy with humane practices.

5. The Matrix of Human Body - Healing Arts & Sacredness

Understanding the relationship between space, culture and belief is formative in the direct experience of seeking healing.

This relationship within the ambit of spirituality in the context of interdisciplinary perspectives is an essential study in healing arts. The author opines that the significance of spirituality in the 'uncertain' quest for alleviation or cure is best comprehended in abstract spaces with very little or no material involvement. This is the traditional view of healing in India. The human body has not evolved further over the past 10,000 years. The author prefers the "Badarayana Brahma Sutras" by Sage Badarayana Vyasa to assure comprehensive healing from the highest abstraction of the human being.

There are two important concepts:

- Rachna Sharira [Anatomy - structure of Human Beings]

6. Kriya Sharira [Physiology - Mechanical, Physical, Bioelectrical, and Biochemical functions of Human Beings]

The author reckons the practice on the basis of timing. "30 Days or One Month is 1 Pitruja Day and Night" and "12 Months or 1 Year is 1 Daiva Day and Night". After 12 months or 1 Year healing happens only in the realms of spirituality.

7 Pitruja Days i.e one week is ample time for the process to become completely independent of the physical being [Kriya Sharira or Physiology] of both the healer and the healed. "Pitruja" is associated with the Fatherly.

"Rachna Sharira" requires another 23 / 33 days that are Matruja to assure the nourishment of the societal framework. Indic scriptures postulate Matruja days as motherly.

The modern medical practices of prescriptions and documentation serve the 40 days spell of time. The necessity to create sacred space in the examination rooms and patient interactions is also justified in this process.

A space can be sacred, providing those who inhabit a particular space with sense of transcendence - being connected to something greater than oneself. The author prefers sacred geometry to make this space analytical enough for studying the science in the healing traditions. The sacredness is inherent in this approach based on Sacred Geometry. It scales quickly even to the societal healing and facilitates the perception of holism in the process.

The core distinction in the Indic healing arts is that, the meta-physical sacredness seamlessly transcends into the beings as expounded in the "Badarayana Brahma Sutras". A matrix with the alphabet assuming the mother-forms is the necessary mapping for both quantitative and qualitative analysis.

7. Conclusions

The biological basis of "Intelligence" has provided the most abstract synergy for the Human-in-the-Loop. Also, the presumption that the basis for the bioelectrical signals is chemical began to be thankfully challenged. Further explorations on Intelligence and Cognition resulted in some noteworthy research. Confronting human intelligence with methods that have no plausible claim to mimic its cognitive processes have always had limited achievement. It is becoming increasingly clear that intelligence operates on a substrate that is not silicon.

Is biology the next natural choice for the substrate?

Genetic vulnerability during development of the human being and evolution that takes an erratic path to complexity have been tough challenges in choosing biology as the substrate.

Complex systems science considers systems with many components. These systems could be physical, biological, or

social. This paper is an exploration on the possible impacts of biology in providing a working model for studying "Human-in-the-Loop" context of evolving complex systems. Human-in-the-Loop is important for assuring safety in the evolving complex system.

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