More effective biomedical experimentation data by CICT advanced ontological uncertainty management techniques

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***Abstract*—**Classical experimental observation process, even in highly ideal operative controlled condition, like the one achieved in current, most sophisticated and advanced experimental laboratories like CERN, can capture just a small fraction only of overall ideally available information from unique experiment. A number of recent reports in the peer-reviewed literature have discussed irreproducibility of results in biomedical research. Some of these articles suggest that the inability of independent research laboratories to replicate published results has a negative impact on the development of, and confidence in, the biomedical research enterprise. Furthermore, poor reporting of health research is a serious and widespread issue, distorting evidence, limiting its transfer into practice, and providing an unreliable basis for clinical decisions and further research. A series of papers published by the Lancet in January 2014 highlighted the problems of waste in biomedical research and the myriad of issues that can disrupt completion and use of high quality research. To get more resilient data and to achive higher result reproducibility, we present an adaptive and learning system reference architecture for anticipatory smart sensing system interface. To design, analyse and test system properties, a simulation environment has been programmed in MATLAB language, called VEDA®. In this way, it is possible to verify and validate through numerical computation the behavior of all subsystems that compose the final combined overall system. Due to its intrinsic self-adapting and self-scaling relativity properties, this system approach can be applied at any system scale: from single quantum system application development to full system governance strategic assessment policies and beyond. The present paper is a relevant contribute towards a new General Theory of Systems to show how homeostatic operating equilibria can emerge out of a self-organizing landscape of self-structuring attractor points.

***Keywords*—**CICT, ontological uncertainty, self-organizing system, wellbeing.

I. Introduction

CLASSICAL experimental observation process, even in highly ideal operative controlled condition, like the one achieved in current, most sophisticated and advanced experimental laboratories like CERN [1], can capture just a small fraction only of overall ideally available information from unique experiment. The remaining part is lost and inevitably dispersed through environment into something we call "background noise" or "random noise" usually, in every scientific experimental endeavor [2]. The amount of information an individual can acquire in an instant or in a lifetime is finite, and minuscule compared with what the milieu presents; many questions are too complex to describe, let alone solve, in a practicable length of time.

A number of recent reports in the peer-reviewed literature [3,4,5,6] have discussed irreproducibility of results in biomedical research. Some of these articles suggest that the inability of independent research laboratories to replicate published results has a negative impact on the development of, and confidence in, the biomedical research enterprise. Furthermore, poor reporting of health research is a serious and widespread issue, distorting evidence, limiting its transfer into practice, and providing an unreliable basis for clinical decisions and further research. A series of papers published by the Lancet [7] in January 2014 highlighted the problems of waste in biomedical research and the myriad of issues that can disrupt completion and use of high quality research.

Current human made application and system can be quite fragile to unexpected perturbation because Statistics can fool you, unfortunately [8]. As the experiences of the 1970s, 1980s, 1990s and 2000s have shown, unpredictable changes can be very disorienting at enterprise level. These major changes, usually discontinuities referred to as fractures in the environment rather than trends, will largely determine the long-term future of organization. They need to be handled, as opportunities, as positively as possible.

Certainly, statistical and probabilistic theory, applied to all branches of human knowledge under the "continuum hypotesis" assumption, have reached highly sophistication level, and a worldwide audience. It is the core of classic scientific knowledge; it is the traditional instrument of risk-taking. Many "Science 1.0" researchers and scientists up to scientific journals assume it is the ultimate language of science. The basic framework of statistics has been virtually unchanged since Fisher, Neyman and Pearson introduced it. Later, the application of geometry to statistical theory and practice has produced a number of different approaches. As an example, in 1945, by considering the space of probability distributions, Indian-born mathematician and statistician

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Calyampudi Radhakrishna Rao (1920-) suggested the differential geometric approach to statistical inference. It largely focuses on typically multivariate, invariant and higher-order asymptotic results in full and curved exponential families through the use of differential geometry and tensor analysis. Also included in this approach are consideration of curvature, dimension reduction and information loss. In this way the so called "Information Geometry" (IG) approach is born. So, modern IG emerged from the study of the geometrical structure of a manifold of probability distributions under the criterion of invariance.

Every approach that uses analytical function applies a top-down (TD) point-of-view (POV) implicitly. These functions belong to the domain of Infinitesimal Calculus (IC). Unfortunately, from a computational pespective, all approaches that use a TD POV allow for starting from an exact global solution panorama of analytic solution families, which offers a shallow local solution computational precision to real specific needs (in other words, from global to local POV overall system information is not conserved, as misplaced precision leads to information dissipation [8]). In fact, usually further analysis and validation (by probabilistic and stochastic methods) is necessary to get localized computational solution of any practical value, in real application. A local discrete solution is worked out and computationally approximated as the last step in their line of reasoning, that started from an overall continuous system approach (from continuum to discrete ≡ TD POV). Unfortunately, the IC methods are NOT applicable to discrete variable. To deal with discrete variables, we need the Finite Differences Calculus (FDC). FDC deals especially with discrete functions, but it may be applied to continuous function too. As a matter of fact, it can deal with both discrete and continuous categories conveniently. In other words, if we want to achieve an overall system information conservation approach, we have to look for a convenient bottom-up (BU) POV (from discrete to continuum view ≡ BU POV) to start from first, and NOT the other way around! Then, a TD POV can be applied, if needed.

Deep epistemic limitations reside in some parts of the areas covered in risk analysis and decision making applied to real problems [8]. As a matter of fact, to grasp a more reliable representation of reality, researchers and scientists need two intelligently articulated hands: both stochastic and combinatorial approach synergically articulated by natural coupling [9]; let's say we need a fresh "Science 2.0" approach. We just have to remember the Relativity's father inspiration quote: "We cannot solve our problems with the same thinking we used when we created them." The current paper can give a relevant contribute to that perspective to achieve practical operative results quite quickly. An example is presented and discussed.

II. Ontological Uncertainty

In 2005, Lane and Maxfield explored the relationship between uncertainty and innovation [10]. They distinguish three kinds of uncertainty: truth uncertainty, semantic uncertainty, and ontological uncertainty, the latter of which is particularly important for innovation processes and scientific research. In truth uncertainty, actors are uncertain about whether well-defined propositions are true or not. Truth uncertainty is the only kind of uncertainty that Savage's decision theory admits [11], where the propositions in question are statements about future consequences. Savage's decision theory [11] claims that the truth uncertainty for all such propositions can be measured in the probability scale. Others maintain Knight's distinction between risk and uncertainty [12]: propositions about risk are probabilizable by reference to a series of fungible propositions with known truth-values: while others, "truly" uncertain, refer to events that have no such reference set and hence, according to Knight their truth uncertainty cannot be measured probabilistically. For De Finetti [13], the distinction is different: propositions whose truth conditions are observable are probabilizable, otherwise they are not. While controversy still smolders about just what the proper domain of probability is, it is certainly restricted to truth uncertainty: the other two kinds of uncertainty are not probabilizable. In semantic uncertainty, actors are uncertain about what a proposition means. Generating new meanings, particularly new attributions of functionality for artifacts and new attributions of identity for agents, is an important part of innovation and scientific research.

The definition of ontological uncertainty depends upon the concept of actors' interactions. Sometimes the entity structure of actors' worlds change so rapidly that the actors cannot generate stable ontological categories valid for the time periods in which the actions they are about to undertake will continue to generate effects. In such cases, we say that the actors face "ontological uncertainty." A quick search on Google about what "made the world faster" returns as first results: the cloud, internet, globalization, technology, wireless communication (and the end of the Cold War). We have begun to design technologies that can take advantage of this increase in the speed of information transmission to develop better short-term insights. Some claim we can now forecast the spreading of flu pandemics or the volatility of stocks using search query data, the results of elections using prediction markets, the demand of new products by tracking their adoption by influential characters in social networks, and better manage prevention of and recovery from extreme events. The availability and rapid analysis of large quantities of big data seems to often be understood as making societies "better." However, global complex socio-economic-ecological systems, formed by a large number of parts at different scales of more or less hierarchical systems, produce emergent patterns and unintended consequences at various scales. A key feature of such complex interactions is that outcomes are inherently uncertain and big data cannot reduce this uncertainty. This is particularly so if the interactions are not just physical, chemical and informational but human, and hence subject to human feeling and reflexive agency. Ontological uncertainty, in contrast to truth or semantic uncertainty, resists the formation of propositions about relevant future consequences. The entities and relations of which such propositions would have to be composed are "simply not known" at the time the propositions would have to be formulated, that is, during the extended present in which action happens.

In the fast-changing emerging scenario of continuous technological innovation and research discoveries, ontological uncertainty hovers around an unaware actor. Sometimes, though, system actors are completely conscious that they are immersed in ontological uncertainty, which offers no particular help in dealing with it. Lane and Maxfield coined the term ontological uncertainty [10] to refer to situations where human agents must make decisions in a context where not only the future trajectory of an entity is uncertain but also its future interactions with other entities and those with each other. It can also be called "radical uncertainty" and is the type recognised by Keynes in his well-known remarks in the General Theory [14].

III. A Fresh Approach

The human world is moving from the Information Age to the Conceptual Age [15], an age that requires both creative and logical-analytical thinking, and for much of the current theoretical work being pursued in the emerging field of neuroscience, computational neuroscience, and biomedical cybernetics. Mankind’s best conceivable worldview is at most a partial picture of the real world, a picture, a representation centered on man. We inevitably see the universe from a human point of view and communicate in terms shaped by the exigencies of human life. However multifarious its make-up, there is a general agreement about the character of the world and the way it is ordered. Explanations of particular phenomena differ from one person to another, but without basic concurrence as to be the nature of things, there would be neither science nor common sense, agreement nor argument.

The most fundamental attributes of our shared view of the world are confined, moreover, to sane, hale, sentient adults. To see the world more or less as others see it, one must above all grow up and to be quite healthy, in a wellness state, even better in a wellbeing state. The very young, like the very ill, are unable to discern adequately what is themselves and what is not. Because we cherish the past as a collective guide to behavior, the general consensus alters very slowly. Scientists as well as laymen do ignore evidence incompatible with their preconceptions. New theories which fail to fit established views are resisted, in the hope that they will prove false or irrelevant; old ones yield to convenience rather than to evidence. The 17th century Galileo Galilei's debates remind us that if you have an unshakable belief in something, then no amount of evidence (or lack of evidence) can convince you otherwise (there are always anti-rationalist objections to everything and anything. It is curious, however, still to hear them in the 21st century rather than in the 17th.)

We need tools able to manage ontological uncertainty quite effectively [16,17]. Although there are many sources of uncertainty, they can be related to two basic areas of uncertainty that are fundamentally different from each other and recognized as traditional reference knowledge from scientific community: natural and epistemic uncertainty. Intrinsic randomness of a phenomenon (e.g. throwing a dice) or natural uncertainty cannot be reduced by the collection of additional data and it stems from variability of the underlying stochastic process. On the other end, epistemic uncertainty results from incomplete knowledge (or lack of information) about the process under study. Unlike natural uncertainty, epistemic uncertainty can be reduced by the collection of additional data.

Statistical and applied probabilistic theory is the core of traditional scientific knowledge; it is the "logic of science"; it is the traditional instrument of risk-taking. Main epistemic uncertainty sources can be referred to three core conceptual areas: a) Entropy Generation (Clausius-Boltzmann), b) Heisenberg Uncertainty Principle and c) Gödel Incompleteness Theorems. Epistemic uncertainty sources are still treated with the traditional approach of risk analysis, which provides an acceptable cost/benefit ratio to producer/manufacturer, but in some cases it may not represent an optimal solution to end user. In fact, deep epistemic limitations reside in some parts of the areas covered in decision making [8]. These limitations are twofold: philosophical (mathematical) and empirical (human known epistemic biases). The philosophical problem is about the decrease in knowledge when it comes to rare events as these are not visible in past samples and therefore require a strong a priori, or an extrapolating theory; accordingly predictions of events depend more and more on theories when their probability is small.

APPLICATION / DOMAIN	Simple payoffs	Complex payoffs
Distribution 1 (“thin tailed”)	Extremely robust to Black Swans	Quite robust to Black Swans
Distribution 2 (“heavy” and/or unknown tails, no or unknown characteristic scale)	Quite robust to Black Swans	**LIMITS of Statistics – extreme fragility to Black Swans**

Fig. 1. The four quadrants. The South-East area (in orange) is where Statistics and models fail us.[20]

In the fourth quadrant of Taleb (Fig. 1, orange square), knowledge is both uncertain and consequences are large, requiring more system robustness [18]. In fact, can we understand health without considering wild diseases and epidemics? Indeed the normal is often irrelevant. Almost everything in social life is produced by rare but consequential shocks and jumps. All the while almost everything studied about social life focuses on the "normal," particularly with "bell curve" methods of inference that tell you close to nothing about natural events. Why? Because the bell curve ignores large deviations, cannot handle them, yet makes us confident that we have tamed uncertainty.

More generally, decision theory, based on a "fixed universe" or a model of possible outcomes, ignores and minimizes the effect of events that are "outside model". A fixed model considers the "known unknowns", but ignores the "unknown unknowns" [19,20]. It is not a word pun and if we can use an analogy, it is like to talk about the difference between "secrets" and "mysteries." Secrets being things that were knowable but we just don’t know them, and mysteries being things that are basically unknowable, as the difficulty that policy-makers have in making decisions about things because of the information they don’t have, the imponderables. The idea of known and unknown unknowns recognizes that the information those in positions of responsibility in government, as well as in other human endeavors, have at their disposal is almost always incomplete. It emphasizes the importance of intellectual humility, a valuable attribute in decision making and in formulating strategy.

It is difficult to accept, to know that there may be important unknowns. The best strategists try to imagine and consider the possible, even if it seems unlikely. They are then more likely to be prepared and agile enough to adjust course if and when new and surprising information requires it, when things that were previously unknown become known [20]. So, we have even to think about uncertainty in the characterisation of uncertainty by counterfactual thinking. Counterfactual thinking is a concept in psychology that involves the human tendency to create possible alternatives to life events that have already occurred; something that is contrary to what actually happened. Counterfactual thinking is exactly as it states: "counter to the facts" [21]. These thoughts consist of the "What if?" and the "If I had only..." that occur when thinking of how things could have turned out differently. Counterfactual thoughts are things that could never possibly happen in reality, because they solely pertain to events that have occurred in the past [21].

While the advantage of differentiating between natural (aleatoric) and epistemic uncertainty in analysis is clear, the necessity of distinguishing between them is not, by an operative point of view. As a matter of fact, epistemic and aleatory uncertainties are fixed neither in space nor in time. What is aleatory uncertainty in one model can be epistemic uncertainty in another model, at least in part. And what appears to be aleatory uncertainty at the present time may be cast, at least in part, into epistemic uncertainty at a later date [22].

To get deeper inspiration, we focus our attention on mammalian brain neurophysiology. In fact, from a neurophysiological point of view, neuroscientist Joseph E. LeDoux finds two amygdala pathways in the brain of the laboratory mouse by the use of fear conditioning and lesion study [23,24]. Although most of the research on the neural basis of conditioned fear has been conducted on animals, fear conditioning procedures can be used in identical ways in humans, according to LeDoux [23]. Information about external stimuli reaches the amygdala by way of direct pathways from the thalamus (the "low road") as well as by way of pathways from the thalamus to the cortex to the amygdala (the "high road"). The direct thalamo-amygadala is a shorter and thus a faster transmission route than the pathway from the thalamus through the cortex to the amygdala. However, because the direct pathway bypasses the cortex, it is unable to benefit from cortical processing. As a result, it can only provide the amygdala with a crude representation of the stimulus. It is thus a quick and dirty processing pathway. The direct pathway allows us to begin to respond to potentially dangerous stimuli before we fully know what the stimulus is. This can be very useful in dangerous situations. However, its utility requires that the cortical pathway be able to override the direct pathway. It is possible that the direct pathway is responsible for the control of emotional responses that we do not understand. The time saved by the amygdala in acting on the thalamic information, rather than waiting for the cortical input, may be the difference between life and death. It is better to have treated a stick as a snake than not to have responded to a possible snake.

Most of what we know about these pathways has actually been learned by studies of the auditory as opposed to the visual system, but the same organizational principles seem to apply. The low road is a pathway which is able to transmit a signal from a stimulus to the thalamus, and then to the amygdala, which then activates a fear-response in the body. This sequence works without a conscious experience of what comprises the stimulus, and it is the fast way to a bodily response (a more primitive mechanism of defense). The high road is activated simultaneously. This is a slower road which also includes the cortical parts of the brain, thus creating a conscious impression of what the stimulus is (a more sophisticated mechanism of defense). "Amygdala hijack" is a term coined by psychologist D. Goleman [25]. Drawing on the work of Joseph E. LeDoux, Goleman uses the term to describe emotional responses from people which are immediate and overwhelming, and out of measure with the actual stimulus because it has triggered a much more significant emotional threat. From the thalamus, a part of the stimulus goes directly to the amygdala (low road) while another part is sent (high road) to the neocortex (the "thinking brain"). If the amygdala perceives a match to the stimulus, i.e., if the record of experiences in the hippocampus tells the amygdala that it is a fight, flight or freeze situation, then the Amygdala triggers the HPA (Hypothalmic-Pituitary-Adrenal) axis and hijacks the rational brain. This emotional brain activity processes information milliseconds earlier than the rational brain, so in case of a match, the amygdala acts before any possible direction from the neo-cortex can be received. If, however, the amygdala does not find any match to the stimulus received with its recorded threatening situations, then it acts according to the directions received from the neo-cortex. When the amygdala perceives a threat, it can lead that person to react irrationally and destructively.

Taking into consideration the neurophysiological findings by LeDoux, differently from the past, it is much better to consider ontological uncertainty [23] as an emergent phenomenon out of a complex system. Then, our dynamic ontological perspective can be thought as an emergent, natural operating point out of, at least, a dichotomy of two fundamental coupled irreducible complementary ideal asymptotic concepts: a) reliable predictability and b) reliable unpredictability.

From TD management perspective, the reliable predictability concept can be referred to traditional system reactive approach (lag subsystem, Closed Logic, to learn and prosper) and operative management techniques. The reliable unpredictability concept can be associated to system proactive approach (lead subsystem, Open Logic, to survive and grow) and strategic management techniques.

To achieve our final goal, overall system must be provided with smart sensing interface which allow reliable real-time interaction with its environment. To behave realistically, system must guarantee both Logical Aperture (to survive and grow) and Logical Closure (to learn and prosper), both fed by environmental "noise" (better… from what human beings call "noise") [2].

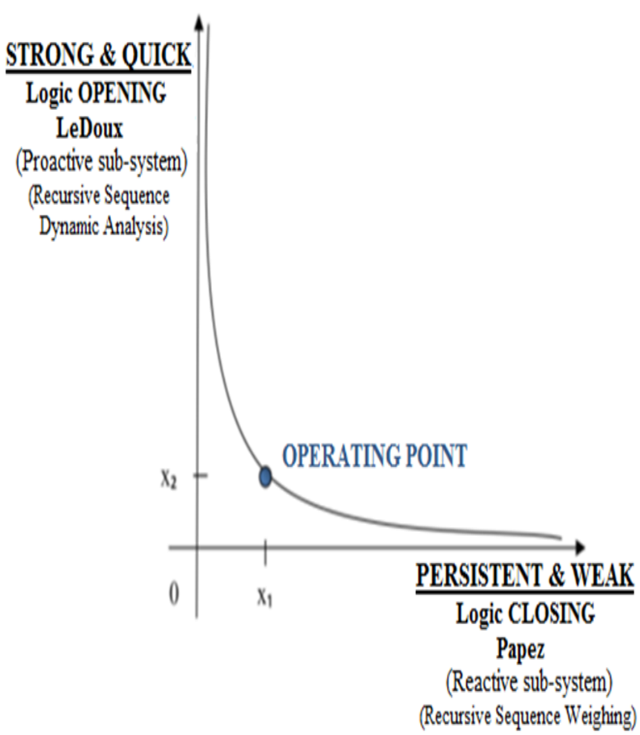

Fig. 2 Operating Point can emerge as a new Trans-disciplinary Reality Level (TRL), based on Two Complementary Irreducible Management Subsystems interacting with their common environment [26].

So, according to previous considerations, at brain level, it is possible to refer to LeDoux circuit ("low road", Logical Aperture) for emotional behavior (i.e. fear, emotional intelligence, etc.) and to Papez circuit ("high road", Logical Closure) for structured behavior (i.e rational thinking, knowledge extraction, etc…) as from Fig.2 [23,24]. Emotional Intelligence (EI) and Emotional Creativity (EC) [25] coexist at the same time with Rational Thinking in human mind, sharing the same input environment information [26]. Therefore, the mathematical method we are looking for, must possess even anticipatory properties, at design level, needed to the realization of system capable to interact with its environment in real time (leading property) [27].

IV. CICT

The first attempt to identify basic principles, to synergically articulate Computational Information Conservation Theory (CICT) by natural coupling to IG, for scientific research and application, has been developing at "Politecnico di Milano University" since the end of last century. In 2013, the basic principles on CICT, from discrete system parameter and generator, appeared in literature and a brief introduction to CICT was given in 2014 [9]. CICT tries to bring classical and quantum information theory together in a single formalism, by considering information not only on the statistical manifold of model states but also from empirical measures of low-level multiplicative noise source generators, related to experimental high-level overall perturbation [2]. CICT showed that long arithmetic division minority components (Remainders, *R*), for long time concealed relational knowledge to their dominant result (Quotient, *Q*), not only can always allow quotient regeneration from their remainder information to any arbitrary precision, but even to achieve information conservation and entropy minimization, in systems modeling and post-human cybernetic approaches [28,29].

Number Theory and modern Numeric Analysis use mono-directional interpretation (left-to-right, LTR) only, for ***Q*** Arithmetic single numeric group generator, so information entropy generation cannot be avoided in current computational algorithm and application [30]. As a matter of fact, traditional digital computational resources are unable to capture and to manage not only the full information content of a single Real Number ***R***, but even Rational Number ***Q*** information content is managed by information dissipation.

On the contrary, according to CICT, it is quite simple to show information conservation and generator reversibility (right-to-left, RTL), by using basic considerations only. Traditional elementary arithmetic long division remainder sequences can be interpreted as combinatorially optimized exponential cyclic sequences (OECS) for hyperbolic geometric structures, as points on a discrete Riemannian manifold, under HG metric, indistinguishable from traditional random noise sources by classical Shannon entropy, and contemporary most advanced instrumentation [2]. Thanks to this brand new knowledge and following this line of generative thinking, it is possible immediately to realize that traditional ***Q*** Arithmetic can be even interpreted, by new eyes, as a highly sophisticated open logic, powerful and flexible LTR and RTL evolutionary, generative, formal numeric language of languages, with self-defining consistent numeric words and rules, starting from elementary generator and relation (you get your specific formal numeric language by just simply choosing your most convenient numeric base to polynomially structure your information). By this new perspective, traditional rational representations are able to capture two different type of information at the same time, both modulus (usual quotient information) and associated intrinsic period information which each combined generator inner phase can be computed from. So, rational information can be better thought to be isomorphic to vector information at least, rather than to usual scalar one only.

The final result is CICT new awareness of a hyperbolic framework of coded heterogeneous hyperbolic structures, underlying the familiar Euclidean surface representation system. CICT emerged from the study of the geometrical structure of a discrete manifold of ordered hyperbolic substructures, coded by formal power series, under the criterion of evolutive structural invariance at arbitrary precision. It defines an arbitrary-scaling discrete Riemannian manifold uniquely, under HG metric, that, for arbitrary finite point accuracy level *L* going to infinity (exact solution theoretically), is isomorphic, even better homeomorphic, to traditional IG Riemannian manifold. In other words, HG can describe a projective relativistic geometry directly hardwired into elementary arithmetic long division remainder sequences, offering many competitive computational advantages over traditional Euclidean approach [2].

In the past five decades, trend in Systems Theory, in specialized research area, has shifted from classic single domain information channel transfer function approach (Shannon's noisy channel) to the more structured ODR Functional Sub-domain Transfer Function Approach (Observation, Description and Representa-tion), according to CICT Infocentric Worldview model (theoretically, virtually noise-free data) [2].

CICT sees rational geometric series as simple recursion sequences in a wider recursive operative framework where all algebraic recursion sequences of any countable higher order include all the lower order ones and they can be optimally mapped to rational number system ***Q*** operational representations and generating functions. For instance, arithmetic progression and Lucas sequences are recursion sequences of the second order. Lucas sequences are certain integer sequences that satisfy Lucas recurrence relation defined by polynomials $Un(P,Q)$ and $Vn(P,Q)$, where Un, Vn are specific polynomials and P, Q are fixed integer coefficients. Any other sequence satisfying this recurrence relation can be represented as a linear combination of the Lucas sequences $Un(P,Q)$ and $Vn(P,Q)$. Famous examples of Lucas sequences include the Fibonacci numbers, Mersenne numbers, Pell numbers, Lucas numbers, Jacobsthal numbers, and a superset of Fermat numbers. CICT is able to fold any recursion sequence of the first order into one digit number D_1, any recursion sequence of second order into a two digit number D_2, any recursion sequence of the third order into a three digit number D_3 and so on to higher orders. Then, you can interpret their asymptotic convergence ratios as increasing accuracy approximations to related asymptotic roots from corresponding first, second, third, ..., *n-th* order equations respectively.

We already know about "self-reference" in mathematics as a statement that refers to itself, for example, as a set that contains itself. Traditionally, such statements lead to paradox, a form of inconsistency. In the informal fallacies self-referential statements are considered poor form. That is true in mathematics and arithmetics when you use a continuum support approach and do not take advantage from the scale relativity finiteness limitations of your real computational resources as CICT does [2,9].

V. RESULTS

In his book "Liber abaci", for the first time Fibonacci (1170-1250) introduced the concept of recursive sequence to the Western culture, with the famous sequence:

$$\mathbf{0}, \mathbf{1}, 1, 2, 3, 5, 8, 13, 21, 34, 55.89, 144, ... \quad (01)$$

in which each term is the sum of the two preceding ones and the numerical sequence composition law can be written:

$$F_n = F_{n-1} + F_{n-2} \quad \text{with } F_0 = 0 \text{ and } F_1 = 1 \;, \quad (02)$$

and in general, $F_n = k_1 * F_{n-1} + k_2 * F_{n-2}$, where k_1, $k_2 = 0,1,2,\ldots\infty$, k_1, $k_2 \in N$, for Generalized Fibonacci Sequences. For original Fibonacci sequence $k_1 = k_2 = 1$.

As a starting point, this relation can be thought as the aggregation of an external information $[F_0, F_1] \equiv [u_1, u_2]$ to internal system status information $[k_1, k_2]$. Therefore, recursive sequence information aggregation offers at least three operational advantages over usual direct polynomial quantification. First, recursive sequence information aggregation does not suffer from the computational polynomial mirroring effect. Second, its asymptotic convergence properties computed by the ratio of successive terms allows the creation of a structured system's behavioral space similar, in computational behavior, to the living organism's homeostasis (i.e. the automatic selection of environment's minimum perturbation level that allows optimal interaction between external information from environment (u) and system internal status information (k) [31], as evidenced by Holling [26]. Third, recursive sequence information aggregation represents a computational method with intrinsic computational anticipatory properties, because it is possible to structure anticipatory computation for successive sequence terms arbitrarily. Then taking any positional index it is possible to compute not only the next one but also those ones at any distance from the current position in an anticipatory way [27]. Moreover, the ratio of Fibonacci sequence's two consecutive numbers, according to the relation:

$$\lim_{n\to\infty} \frac{F_{(n+1)}}{F_{(n)}} = \phi \quad (03)$$

asymptotically converges to the golden number, property discovered by Kepler [32], providing us with recurrence relation functional closure.

For this simplest case, the recursive aggregation law of information can be easily extended to three consecutive terms (starting by trinomial 0,0,1, third order relation, $m=3$), four successive terms (starting by quadrinomial 0,0,0,1, fourth order relation , $m=4$), j successive terms (starting by m-nomial formed by j zeroes, plus one 1, $(j+1)^{th}$ order relation, ($m=j+1$), and in general we can write, in compact form, recursive relations as function of three parameters, $a_n = a(m, k, u)$, as specified previously, where m is the recurrence relation order.

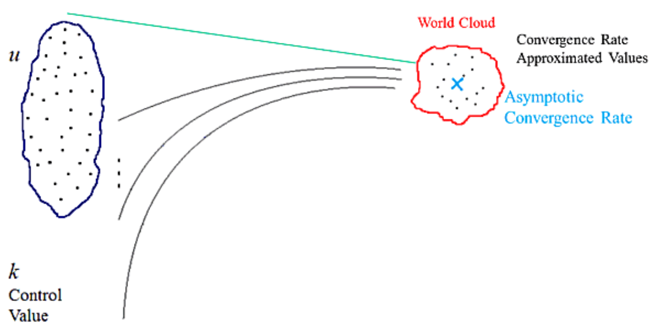

Fig. 3 Control Value k allows to arrange external inputs u into symbolic string information with different convergence rate approximation around their convergence rate asymptotic value (World Cloud). For different k values, a landscape of world clouds can start self-organizing into a Baire Space. Control Value k selects recurrence series asymptotic convergence rate (Attractor Point), which different input u approximated rates are self-arranging modularly (World Cloud) around.

In this way, we can allow for articulated information aggregation even in a networking environment and computing their related asimptotic functional closures immediately. Therefore, it is possible to compute recursively further numerical sequences asymptotically converging to irrational limits or completely diverging as function of external information input. In this way system can search automatically for a minimum environmental perturbation level (system internal status) useful to insure sequence asymptotically convergence to get vital information from system environment (self-regulation and learning as quest for the difference that makes the difference, probing by probing...). Then, homeostatic operating equilibria can emerge out of a self-organizing landscape of self-structuring attractor points with their World Cloud (Fig.3).

Irrational numeric limit families, identified by converging recursive numeric sequences allow the structuring of a mathematical Baire's Space. A Baire space consists of countably infinite sequences with a metric defined in terms of the longest common prefix: the longer the common prefix, the closer a pair of sequences. What is of interest to us here is this longest common prefix metric, which we call the "Baire distance", which is an ultrametric distance [33,34,35]. Baire's Space allows to manage numeric information in a way useful to synthetise quick and raw system primary response "to survive and grow." Furthermore, in this way system can even automatically self-organize and structure numeric families with different numerical closure to conserve overall system information (Generalized Fibonacci Systems, and information conservation by irreducible complementary system) [2]. But, never forget one of Robert Rosen's fundamental lessons: human formal systems are unable to capture enough knowledge to model natural system completely [27]. You have to model natural system with deep awareness to grasp a part of it only! What you will always get is uncertainty awareness evolutive finite scale relativity precision from never-ending natural evolution. So the best you can do is to find your best strategic management solution to handle arbitrary incomplete knowledge and system uncertainty precision [2,9].

Rational recursive sequence represents a convenient mathematical method that holds anticipatory proprieties, because it is possible to implement the anticipatory computation of any recursive sequence's term. Taking arbitrarily any current positional index, it is possible to describe not only the next term but also terms at a certain distance from the current one in an anticipatory way, compared with the current positional index, by implementing its primary relation recursion conveniently. Specifically, starting from the recursive rule that indicates the next term to the current one, it is possible to structure a set of rules that allows to obtain recursive sequence's terms at different distance, defining a set of registers that, working in parallel, are able to provide values with the desired anticipation level immediately. For example, considering second order (m = 2) recursive relations $a_n = a(2, k, u)$, where k and u are 2-d vectors $[k_1, k_2]$ and $[u_1, u_2]$ respectively, and where the $(n + 1)$-th to the current n-th term is obtained in the following way:

$$a_{n+1} = k_1 * a_n + k_2 * a_{n-1} , \qquad (04)$$

where $a_{n-1} = u_1 = 0$ and $a_n = u_2 = 1$, $k_1 = k_2 = 1$, for the Fibonacci sequence. Then, we can specify recursion derived relations to compute appropriate terms at any arbitrary distance from the current position n. As an example, we define the following relations that are valid for computing terms to the distance n+5 from the current one, depending, for instance, on parameters $[k_1, k_2] = [1, 1]$ and $[k_1, k_2] = [2, 2]$. These recursive relations can be used in parallel, respectively, to provide the terms of sequence in an anticipatory way simultaneously. So in the case of $[k_1, k_2] = [1, 1]$, aggregation rules are as follows:

$$\begin{aligned} a_{n+2} &= 2 * a_n + 1 * a_{n-1} \\ a_{n+3} &= 3 * a_n + 2 * a_{n-1} \\ a_{n+4} &= 5 * a_n + 3 * a_{n-1} \\ a_{n+5} &= 8 * a_n + 5 * a_{n-1} \\ &\dots \end{aligned} \qquad (05)$$

In the case of values $[k_1, k_2] = [2, 2]$ we obtain the following aggregation rules:

$$\begin{aligned} a_{n+2} &= 6 * a_n + 4 * a_{n-1} \\ a_{n+3} &= 16 * a_n + 12 * a_{n-1} \\ a_{n+4} &= 44 * a_n + 32 * a_{n-1} \\ a_{n+5} &= 120 * a_n + 88 * a_{n-1} \\ &\dots \end{aligned} \qquad (06)$$

In general for any vector $[k_1, k_2]$ and for any order m, it is always possible to formulate rules associated to their primary recursion relation: these rules allow for the parallel anticipatory computation of recursive sequence's term at any distance from the current term position n.

To synthetize more organized and articulated, but slower, system response "to learn and prosper", it is necessary to structure recursive information into an "ordered polynomial reference", by "polynomial weighing" mapping, to obtain "coherent perception" [31]. Polynomial weighing is key numeric operation to map recursive sequence information representation into polynomial format corresponding to combinatorially OECS, folded into rational number operative representation (Fig.4) [2,9].

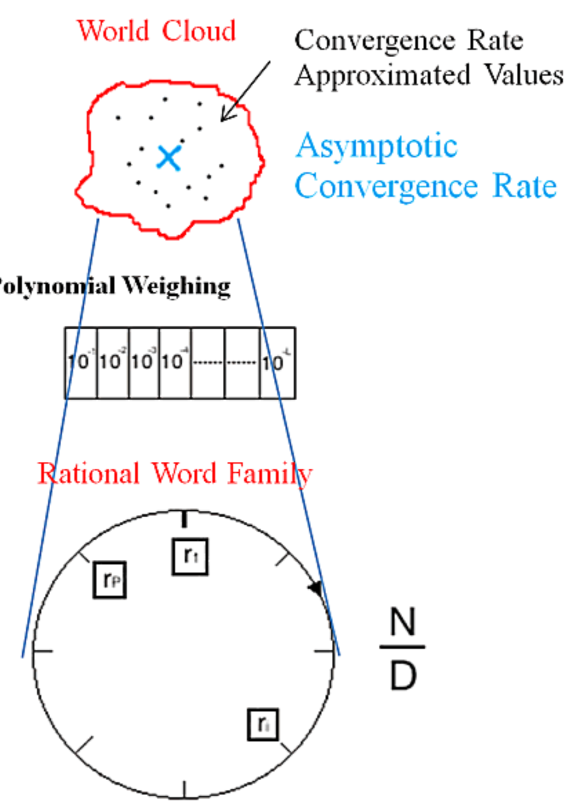

Fig. 4 Polynomial Weighing mapping allows the modular mapping of each 2-D approximated algebraic irrational World Cloud into a corresponding Rational Word Family. Denominator D identifies Rational Word Family. Numerator N identifies algebraic rational approximations of irrational values (attractor points) as component inside that Family.

So, we get a sequence of different structuring operations to get external information more and more coherently formatted to system internal status to arrive to a system "coherent perception" of external information. In this way, a natural balanced "Operating Point" can emerge, as a new Trans-disciplinary Reality Level, from an irreducible complementary ideal asymptotic dichotomy: Two Coupled Complementary Irreducible Information Management Subsystems. The overall adaptive and learning system reference architecture for anticipatory smart system interface (Interaction Interface System, IIS) is depicted in Fig.5. The simple recursive information aggregation method can be used even for advanced ISS (Inner Safety System) in advanced biomedical and healthcare system development, for neuroperception, organ level modeling, bio-transduction functions, etc.

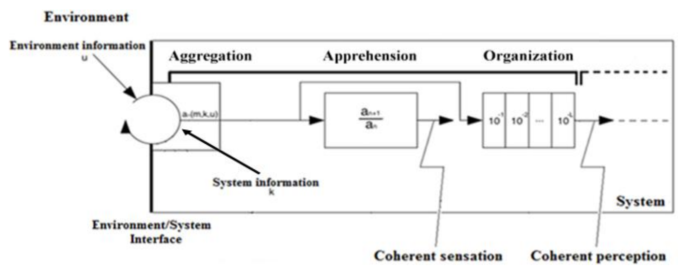

Fig. 5 Interaction Interface System (IIS) Reference Architecture [31]: Apprehension (Open Logic Section); Organization (Closed Logic Section).

Due to its intrinsic self-organizing and self-scaling properties, this system approach can be applied at any system scale: from single health application development to full healthcare system governance strategic simulation and assessment application [28]. It can allow both quick and raw system response (Open Logic response, to grow and survive) and slow and accurate information unfolding for future response strategic organization (Closed Logic response, to learn, to adapt and prosper) by coherently formatted operating point [28].

VI. An Application Example

To design, analyse and test IIS and ISS system properties, a simulation environment has been designed, developed and implemented, programmed in MATLAB language, called VEDA® (Visualization of Evolutionary Dynamics Application), at Politecnico di Milano University. VEDA® system dynamics simulation toolbox offers a high level simulation flexibility by user-optimized graphic interface to get easier simulation task, to design, analyze and synthetize complex dynamical system behaviour. In this way, it is possible to study natural complex dynamic's simulation, to verify and validate through numerical computation and displaying the behavior of all subsystems that compose the final combined overall system performance. So, according to desired system parameters, to validate the choice of optimal parameters set, for a specific embodiment, is quite straightforward [31].

Here, as an application example, we use VEDA for data processing and pattern recognition in a cognitive task application (spoken sentence comprehension) using electroencephalography (EEG) data [36] and event related potentials (ERP) preprocessing [37].

Brain ultimately depends on the knowledge of large-scale networks organization (i.e. Default mode net, Salience net, Central-executive net, Mirroring net, Mentalizing net, etc.)

[38]. The Default Mode Network (DMN) regions exhibit deactivation during a wide variety of resource demanding tasks. However, recent brain imaging studies reported that they also show activation during various cognitive activities. In addition, studies have found a negative correlation between the DMN and the Working Memory Network (WMN). Activation of these network regions is affected by allocation of attentional resources to the task relevant regions due to task demands. The core DMN regions exhibit activation during task preparation and deactivation during task execution [38]. Human brain contains broadly distributed functional networks that can each be redescribed as basic psychological operations that interact to produce a range of mental states, including, but not limited to, anger, sadness, fear, disgust, and so on. When compared to the faculty psychology approach, this approach provides an alternative functional architecture to guide the design and interpretation of experiments in cognitive neuroscience.

Continued progress in understanding of cognitive function and dysfunction will depend on the development of new techniques for imaging structural and functional brain connectivity, as well as on new computational tools and methods for investigating deep dynamic interactions within and between brain networks. For instance, spoken sentence comprehension relies on rapid and effortless temporal integration of speech units displayed at different rates. Temporal integration refers to how chunks of information perceived at different time scales are linked together by the listener in mapping speech sounds onto meaning. The neural implementation of this integration remains unclear [40]. The role of short and long windows of integration in accessing meaning from long samples of speech plays a fundamental role. In a cross-linguistic study, the time course of oscillatory brain activity between 1 and 100 Hz, was recorded using EEG, during the processing of native and foreign languages.

Oscillatory responses in a group of Italian and Spanish native speakers while they attentively listen to Italian, Japanese, and Spanish utterances, played either forward or backward, was recorded. The results show that both groups of participants display a significant increase in gamma band power (55-75 Hz) only when they listen to their native language played forward. The increase in gamma power starts around 1000 msec after the onset of the utterance and decreases by its end, resembling the time course of access to meaning during speech perception [40]. In contrast, changes in low-frequency power show similar patterns for both native and foreign languages. So, it seems that gamma band power reflects a temporal binding phenomenon concerning the coordination of neural assemblies involved in accessing meaning of long samples of speech [40]. The final goal is to try to reach a better understanding of how the human brain produces cognition.

Continuous EEG data were acquired using a 64-channel electrode cap with standard 10-10-system electrode placement [36]. A typical ERP preprocessing is applied to EEG data recording [37]. The ERP is small (a few microvolts) in comparison to the EEG (about 50 microvolts). Thus, analysis generally begins with procedures to increase the discrimination of the signal (the ERP) from the noise (background EEG). The most common of these procedures involves averaging samples of the EEG that are time-locked to repeated occurrences of a particular event or type of event. The number of samples used in the average is related to the signal-to-noise ratio [41]. However, in all cases, the samples are selected so that they bear a consistent temporal relationship to the event. Because aspects of the EEG that are not time-locked to the event are assumed to vary randomly from sample to sample, the averaging procedure should result in a reduction of these noise potentials, rendering the signal, event-related potentials visible [37]. Because ERPs are always measured as differences in potential between two recording locations, they will also vary as a function of the electrode site at which they are recorded, as well as the reference electrode used. Spatial (topographic) distribution is regarded as an important discriminative characteristic of the ERP [42]. Therefore, positive and negative peaks in the ERP are generally described in terms of their characteristic scalp distribution, as well as their polarity, and latency.

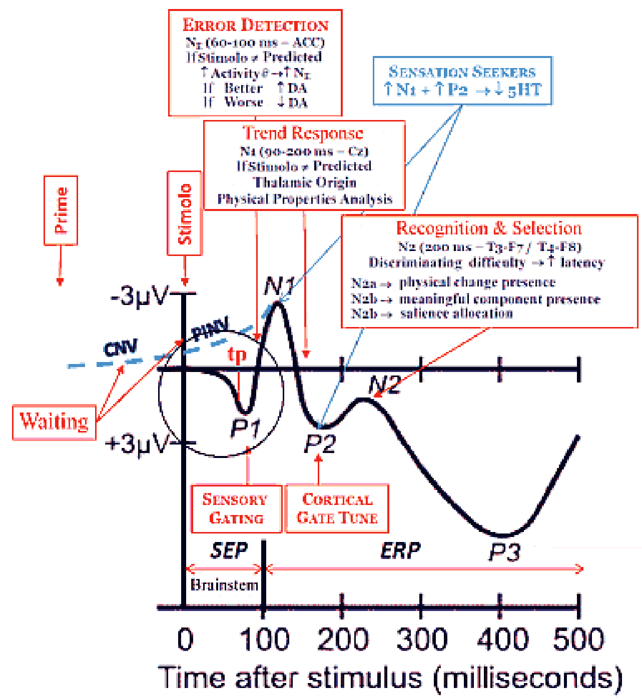

Fig. 6 A typical ERP preprocessing from EEG data recording for our example where you can see a few standard reference points: Main Stimulus starting at t = 0, tp onset ending, P1 Sensory Gating, Ne Error Detection, N1 Trend Response, P2 Cortical Gate Tune, N2 Recognition and Selection, N3 New Meaningful Stimuli Attention Shift (see text).

Let's assume that a standard ERP for our example is reportend in Fig.6 where you can see a few standard temporal reference points: Main Stimulus starting at t = 0, tp onset ending, P1 Sensory Gating, Ne Error Detection, N1 Trend Response, P2 Cortical Gate Tune, N2 Recognition and Selection, N3 New Meaningful Stimuli Attention Shift, etc.

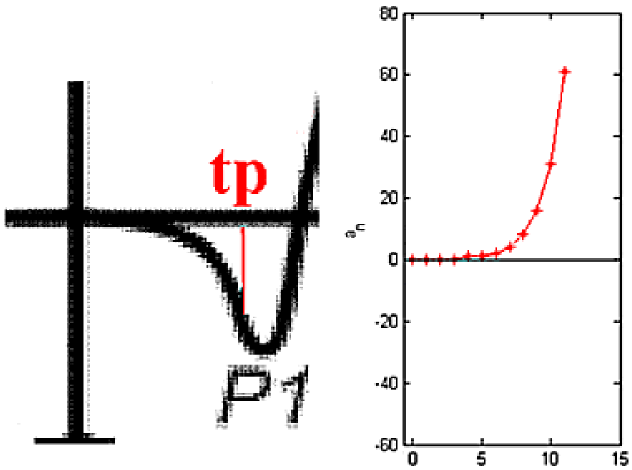

Fig. 7 Enlargement of the ERP onset inside the black circle of Fig.6. Right side: CICT fitting of the function on the left side from t = 0 to instant tp, by a divergent LTR recursive sequence (see text).

Usually, the recording temporal behavior interpretation is quite easy from t = 0 to tp. In fact, the usual assumption is that only one or two components start responding to input stimuli. As farer as you go from t = 0, subsystems behavior start to show interplay couplings getting more difficult to arrive to a clear interpretation of single subsystem contribute to overall system response. The labels given to the peaks of an ERP waveform often include descriptors of polarity and latency. In Fig.7, on the left side, you can see an enlargement of the early ERP P1 onset inside the black circle of Fig.6 (from t = 0 to tp). Traditionally, although the exogenous/endogenous distinction provides a useful method for classifying many ERP components, there are potentials that possess characteristics that are intermediate between these two groups, and are therefore called "mesogenous" [42].

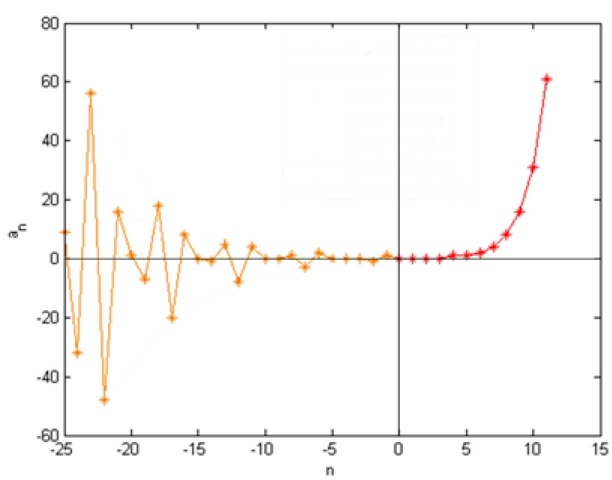

Fig. 8 Divergent LTR recursive sequence (upper right side) generated by apparently irregularly arranged point RTL divergent sequence on the left (see text).

The N1 is such an example, as it is assumed to be sensitive to both the physical properties of the stimulus and the nature of the interaction between the subject and the event (e.g., whether the event is to be attended) [37]. On the right side of Fig.7 a VEDA fitting, computational model of the P1 onset response is synthezised by a fifth order LTR recurrence relation (please, note that the function is flipped according to recording polarity). Now, according to CICT, it is possible to get a unique RTL function extension by information conservation, as reported on the left side of Fig.8, giving a divergent oscillating function, apparently difficult to offer any immediate interpetation. Nevertheless, applying the information coherent combinatorial approach allowed by CICT, VEDA toolbox displays our final result in the left side of Fig.9. As a matter of fact, the previous divergent oscillating function is the coherent combination of five combinatorially optimized subsequences. So, even the previously assumed simple interpretation of the onset response from t = 0 to tp should be more carefully revisited. In fact, according to VEDA interpretation, it could be the overall response result due to the coherent composition of five different subsytem outputs, which start to cooperate to one another immediately on input stimuli.

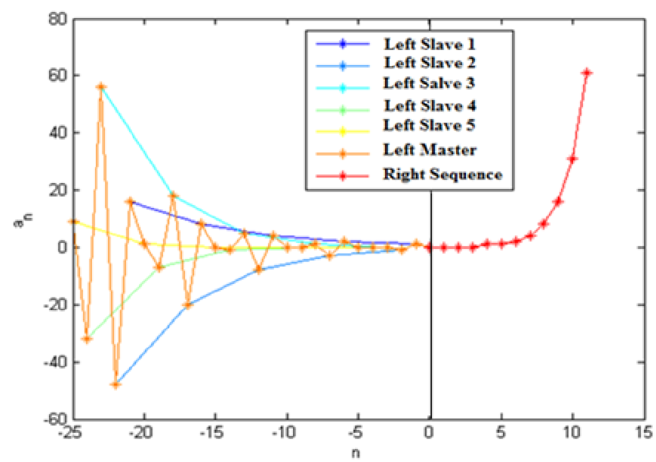

Fig. 9 Coherent combination of five simple RTL slave subsequences to synthesize the unique LTR master sequence on the right side (see text).

VII. Conclusion

The major added value of our paper is provided by our fresh approach to ontological uncertainty management and by our new idea of system articulated interaction, defined by inner and outer system information aggregation. It can allow both quick and raw system response (to survive and grow) and slow and accurate information unfolding for future response strategic organization (to learn and prosper) by coherently formatted operating point [31]. Now, new advanced systemic information application can successfully and reliably manage a higher system complexity than current ones, with a minimum of design constraints specification and less system final operative environment knowledge at design level.

For instance, according to Fig.2, at brain level, it is possible to refer to LeDoux circuit (Logical Aperture) for emotional behavior (i.e. fear, emotional intelligence, etc…) and to Papez circuit (Logical Closure) for structured behavior (i.e rational thinking, knowledge extraction, etc…) [23,24]. Emotional Intelligence (EI) and Emotional Creativity (EC) [25] coexist at the same time with Rational Thinking in human mind, sharing the same input environment information [26]. Then, operating point can emerge as a trans-disciplinary reality level from the interaction of two complementary irreducible, asymptotic ideal coupled subsystems with their common environment. To behave realistically, overall system must guarantee both Logical Aperture (to get EI and EC, to survive and grow) and Logical Closure (to get Rational Thinking, to learn and prosper), both fed by environmental "noise" (better… from what human beings call "noise") [2]. In fact, natural living organism does perturb its environment, but only up to the level it is perturbed in turn by its own environment both to survive and grow, no more [26]. Due to its intrinsic self-scaling relativity properties, this system approach can be applied at any system scale: from single quantum system application development to full system governance strategic assessment policies and beyond [28]. We can use the same nonlinear logic approach to guess a convenient basic architecture for Anticipatory Learning System (ALS) to get realistic modeling of natural behaviour to be used in High Reliable Organization (HRO) application development. As an example, we showed that traditional data processing and pattern recognition in a cognitive task application (spoken sentence comprehension), using electroencephalography (EEG) data and ERP preprocessing, can offer a shallow interpretation of experimental data unfortunately. A deeper interpretation can be reached by CICT approach and VEDA analysis. In this case, brainsteam function can be exploited much better for system modeling. The overall response result emerges out of the coherent composition of five different subsytem outputs, which start to cooperate to one another immediately on input stimuli onset. CICT coherent representation precision leads to more experimental information clarity and conservation. VEDA® is an original simulation environment developed to validate complex dynamical system modeling. IIS and ISS are two pivotal concepts to develop safer, more adequate, effective and efficient solutions for competitive safety systems and human wellbeing.

As a matter of fact their basic operational concepts can be conveniently and successfully extended to many other advanced Business and HRO application areas, with no performance or economic penalty, to develop more and more competitive application. For instance, at a higher level of abstraction, environmental noise input information to be aggregated to system internal status information can provide a structured homeostatic synthetic operating point as a reference for further inquiry. Then, System Interaction by internal and external information aggregation can allow both quick and raw response (Open Logic response, to grow and survive) and slow and accurate information for future response strategic organization (Closed Logic response, to adapt and prosper) by coherently formatted operating point information. For closed logic Reactive Management system, we can choose from different documented operational alternatives offered by literature, like Deming's PDCA Cycle [43], Discovery-Driven Planning [44], etc…, while for open logic Proactive Management system, we can choose from Boyd OODA Cycle (1987) [45], Theory-Focused Planning [46,] etc… As a simple example, PDCA's cycle (Reactive Management) and OODA's cycle (Proactive Management) can be selected to represent two corresponding complementary irreducible sub-systems for advanced integrated strategic management. Then, our final operative reference architecture, for Safety and Effectiveness Health Systemic Governance, is given as from Fig.10.

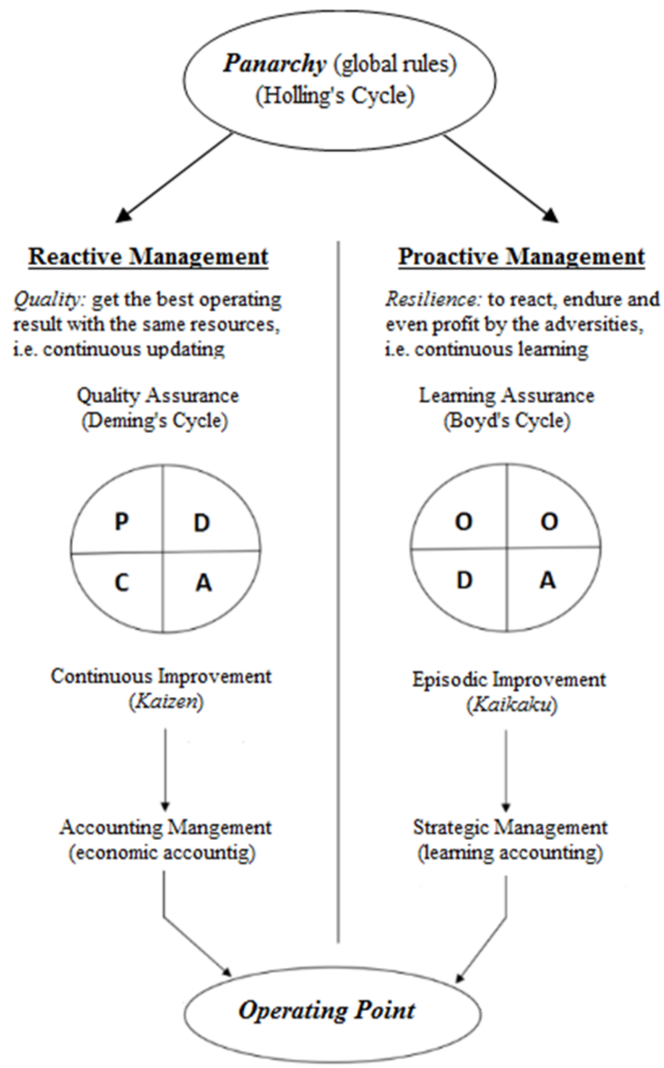

Fig. 10 Final Architecture for Safety and Effectiveness Health Systemic Governance.

Specifically, advanced wellbeing applications (AWA), high reliability organization (HRO), mission critical project (MCP) system, very low technological risk (VLTR) and crisis management (CM) system will be highly benefited mostly by CICT newer approach and related techniques. The present paper is a relevant contribute towards a new General Theory of Systems to show how homeostatic operating equilibria can emerge out of a self-organizing landscape of self-structuring attractor points.

REFERENCES

[1] C. E. U.: European Laboratory for Particle Physics, Conseil Européen pour la Recherche Nuclaire, 2013.

[2] R. A. Fiorini, "How Random is Your Tomographic Noise? A Number Theoretic Transform (NTT) Approach," *Fundamenta Infomaticae*, Vol.135, No.1-2, 2014, pp.135-170.

[3] C.G. Begley and L.M. Ellis, *Nature*, No.483, 2012, pp.531–533.

[4] J.P.A. Ioannidis, *PLoS Med*., No.2, 2005, e124.

[5] A. Mobley, S. K. Linder, R. Braeuer, L. M. Ellis, L. Zwelling, *PLoS ONE*, No.8, 2013, e63221.

[6] R. Nuzzo, "Scientific method: Statistical errors," *Nature*, Vol.506, 13 February 2014, pp.150-152. Available: http://www.nature.com/news/scientific-method-statistical-errors-1.14700

[7] I. Chalmers, M. B. Bracken, B. Djulbegovic, S. Garattini, J. Grant, A. M. Gülmezoglu, et al., "How to increase value and reduce waste when research priorities are set," *Lancet*, Vol.383, No.9912, 2014, pp.156-165. PubMed PMID: 24411644

[8] N. N. Taleb, *Silent Risk*. Preliminary Book Draft, January, 2015.

[9] R. A. Fiorini, "Computational Information Conservation Theory: An Introduction," in *2014 Proceedings of the 8th International Conference on Applied Mathematics, Simulation, Modelling (ASM '14)*, N.E. Mastorakis, M. Demiralp, N. Mukhopadhyay, F. Mainardi, eds., Mathematics and Computers in Science and Engineering Series, No.34, NAUN Conferences, WSEAS Press, November 22-24, 2014, Florence, Italy, pp.385-394, ISSN: 2227-4588, ISBN: 978-960-474-398-8.

[10] D. A. Lane and R. R. Maxfield, "Ontological Uncertainty and Innovation," *J. Evol. Econ*., No.15, Springer-Verlag, 2005, pp.3–50.

[11] L. J. Savage, *The foundations of statistics*. NewYork: Wiley, 1954.

[12] F. Knight, *Risk, uncertainty and profit*. Boston: Houghton-Mifflin, 1921.

[13] B. DeFinetti, *Theory of probability*. New York:.Wiley, 1990.

[14] J. M. Keynes, *The General Theory of Employment, Interest and Money*. London: Macmillan, 1971 (first ed. 1936).

[15] D. H. Pink, *A Whole New Mind - Moving From the Information Age to the Conceptual Age*. New York, NY: Penguin Group, Riverhead PinkBooks, 2005

[16] R. A. Fiorini, "Stronger Physical and Biological Measurement Strategy for Biomedical and Wellbeing Application by CICT," in *2014 Proceedings of the 3rd International Conference on Health Science and Biomedical Systems (HSBS '14)*, N.E. Mastorakis, Atsushi Fukasawa, eds., Series: Recent Advances in Biology and Biomedicine Series No.6, NAUN Conferences, WSEAS Press, November 22-24, 2014, Florence, Italy, pp.36-45, ISSN: 1790-5125, ISBN: 978-960-474-401-5.

[17] R. A. Fiorini, "Stronger Quantum Decoherence Incomputability Modeling by CICT," in *2014 Proceedings of the 3rd International Conference on Applied and Computational Mathematics (ICACM '14)*, NAUN Conferences, WSEAS Press, December 29-31, Geneva, Switzerland.

[18] N. N. Taleb, "The Fourth Quadrant: a Map of the Limits of Statistics," 2014. Available: http://edge.org/conversation/the-fourth-quadrant-a-map-of-the-limits-of-statistics

[19] E. Morris, "The Certainty of Donald Rumsfeld," *The New York Times*, March 25, 2014. Available: http://opinionator.blogs.nytimes.com/tag/the-certainty-of-donald-rumsfeld/

[20] D. Rumsfeld, *Known and Unknown: A Memoir*. New York: Penguin, 2011.

[21] N. Roese, "Counterfactual thinking," *Psychological Bulletin*, Vol.121, No.1, 1997, pp.133–148.

[22] T. C. Hanks, and C. A. Cornell, "Probabilistic Seismic Hazard Analysis: A Beginner's Guide," in *Proceedings of the Fifth Symposium on Current Issues Related to Nuclear Power Plant Structures, Equipment and Piping*, Raleigh, N.C.: North Carolina State University, 1994, pp.I/1-1 to I/1-17.

[23] J. LeDoux, *The Emotional Brain, The Mysterious Underpinnings of Emotional Life*. Great Britain: Weidenfeld & Nicolson, 1998.

[24] J. LeDoux, *Synaptic Self, How Our Brains Become Who We Are*. New York: Viking Penguin, 2002.

[25] D. J. Goleman, *Emotional Intelligence: Why It Can Matter More Than IQ*. New York: Bantam Books, 1995.

[26] L. H. Gunderson and C. S. Holling, Eds, *Panarchy: understanding transformations in human and natural systems*. Washington: DC: Island Press, 2002.

[27] Rosen, R., *Anticipatory Systems*. Oxford: Pergamon Press, 1985.

[28] R. A. Fiorini and G. F. Santacroce, "Economic Competitivity in Healthcare Safety Management by Biomedical Cybernetics ALS," in *2013 Proc. International Symposium, The Economic Crisis: Time For A Paradigm Shift -Towards a Systems Approach*, Universitat de València, January 24-25, 2013.

[29] R. A. Fiorini and G. F. Santacroce, "Systems Science and Biomedical Cybernetics for Healthcare Safety Management," in *2013 Proc. International Symposium, The Economic Crisis: Time For A Paradigm Shift - Towards a Systems Approach*, Universitat de València, January 24-25, 2013.

[30] R. A. Fiorini and G. Laguteta, "Discrete Tomography Data Footprint Reduction by Information Conservation," *Fundamenta Informaticae*, Vol.125, No.3-4, 2013, pp.261–272.

[31] A. V. Collini and C. Cesario, "Sistemi a sicurezza intrinseca per la sanità," Master of Science Thesis, Biomedical Engineering Department, Politecnico di Milano, Milano, Italy, 2012.

[32] J. J. Tattersall, *Elementary number theory in nine chapters*, 2nd ed. Cambridge: Cambridge University Press, 2005, p.28.

[33] F. Murtagh, "On ultrametricity, data coding, and computation," *Journal of Classification*, No.21, September 2004, pp.167-184.

[34] F. Murtagh, "Identifying the ultrametricity of time series," *The European Physical Journal B*, Vol.43, No.4, February 2005, pp.573–579.

[35] F. Murtagh, "Downs, G., Contreras, P., Hierarchical clutering of massive, high dimensional data sets by exploiting ultrametric embedding," *SIAM-Journal on Scientific Computing*, Vol.30, No.2, February 2008, pp.707-730.

[36] M. R. Nuwer, G. Comi, R. Emerson, A. Fuglsang-Frederiksen, J. M. Guerit, et al., "IFCN standards for digital recording of clinical EEG," International Federation of Clinical Neurophysiology. Electroencephalogr., *Clin. Neurophysiol.*, No.106, 1998, pp.259–261.

[37] M. Fabiani, G. Gratton, K. D. Federmeier, "Event-Related Brain Potentials: Methods, Theory, and Applications," in *Handbook of Psychophysiology*, J.T. Cacioppo, L.G. Tassinary, G.G. Berntson, eds, Cambridge: Cambridge University Press, Third Ed., pp.85-119.

[38] S. L., Bressler and V. Menon, "Large-scale brain networks in cognition: emerging methods and principles," *Trends in Cognitive Sciences*, No.14, 2010, pp.277–290.

[39] H. Koshino, T. Minamoto, K. Yaoi, M. Osaka, N. Osaka, "Coactivation of the Default Mode Network regions and Working Memory Network regions during task preparation," *Nature Scientific Reports*, Vol.4, No.5954, 2014, pp.1-8.

[40] M. Peña, and L. Melloni, "Brain oscillations during spoken sentence processing," *J. Cogn. Neurosci.*, Vol.24, No.5, May 2012, pp.1149-64. doi: 10.1162/jocn_a_00144. Epub 2011 Oct 7.

[41] P. Billingsley, *Probability and Measure*. New York: Wiley, 1995.

[42] E. Donchin, W. Ritter, W.C. McCallum, "Cognitive psychophysiology: The endogenous components of the ERP," in *Event-related Brain Potentials in Man*, E. Callaway, P. Tueting, S. Koslow, Eds. New York: Academic Press, 1978.

[43] T. Ohno, *Workplace Management*, Special 100th Birthday Edition, 1 edition. New York: NY: McGraw-Hill Professional, 2012.

[44] G. McGrath, R. MacMillan, I.C. MacMillan, "Discovery Driven Planning: Turning Conventional Planning on its Head," *Harward Business Review*, 1995.

[45] F. P. B. Osinga, *Science, Strategy and War: The Strategic Theory of John Boyd*. New York, NY: Routledge, 2006, 1 edition.

[46] V. Govindarajan and C. Trimble, "Strategic Innovation and the science of learning," *MIT SLOAN Management Review*, Vol.45, No.2, Winter 2004, pp.67-75.

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