Some resonances between Eastern thought and Integral Biomathics in the framework of the WLIMES formalism for modelling living systems

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Abstract
Forty-two years ago, Capra published "The Tao of Physics" [105]. In this book (page 17) he writes: *"The exploration of the atomic and subatomic world in the twentieth century has …. necessitated a radical revision of many of our basic concepts"* and that, unlike 'classical' physics, the sub-atomic and quantum "modern physics" shows resonances with Eastern thoughts and "*leads us to a view of the world which is very similar to the views held by mystics of all ages and traditions.*" This article stresses an analogous situation in biology with respect to a new theoretical approach for studying living systems, *Integral Biomathics* (IB), which also exhibits some resonances with Eastern thought. Stepping on earlier research in cybernetics[1] and theoretical biology[2], IB, has been developed since 2011 by over 100 scientists, from a number of disciplines who have been exploring a substantial set of theoretical frameworks. From that effort, the need for a robust core model utilizing advanced mathematics and computation adequate for understanding the behavior of organisms as *dynamic wholes* was identified. At this end, the authors of this article have proposed WLIMES [6], a formal theory for modeling living systems integrating both the Memory Evolutive Systems [14] and the Wandering Logic Intelligence [9]. Its principles will be recalled here with respect to their resonances to Eastern thought.

Key words:
– Integral Biomathics, Artificial/Synthetic and Natural Life, Phenomenology, Eastern Philosophy, Higher-Order Logic, Wandering Logic Intelligence, Memory Evolutive Systems.

1. Introduction

Biology is classically divided into three conceptual levels (Fig.1). The fundamental level for practitioners is characterized by what can be observed, measured and processed. In life sciences, this empirical level is usually regarded as the 'omics' disciplines: genomics, proteomics, metabolomics, biomics and phenomics. Rich tools abound here. Being essentially quantitative and geometric in nature, this data is easily handled by computers. By assigning semantics and implied causality to it researchers can extract information and bring it up to the next 'logics' level to devise hypotheses, which are tested against more data to develop a theory. Usually, ordinary science is conducted in the cycle between these two levels: theorize, experiment, measure, re-theorize. The third epistemological level concerns the whole living being and how it works as a larger assembly of systems. Unfortunately, summing reductionist theories does not sufficiently inform here. The lore about the "nature of laws in nature" has changed, [193-195, 7]. We need to adopt a more holistic and 'organic' view of life proposed by Eastern philosophies and some novel Western approaches ([161-162], in this special issue). Indeed, living systems have essential dynamics at the systems level, which overlap and might not have clear physiological definition [11]. For example, the immune system has evolved as a collaborative organization for hundreds of millions of years, existing both in plants and multicellular organisms. Many autoimmune and inflammation disorders can be attributed to poor sensing by different parts of this system. To intercede, sustainable models are needed to unite the different levels of representation.

[1] the Macy conferences (1946-1953) with McCulloch, Pitts, Bateson, Shannon, Mead, von Foerster, Wiener, von Neumann and others.
[2] the Villa Serbelloni conferences (1965-1968) with Waddington, Thom, Goodwin, Conrad, Smith, Rosen, Kauffman and others.

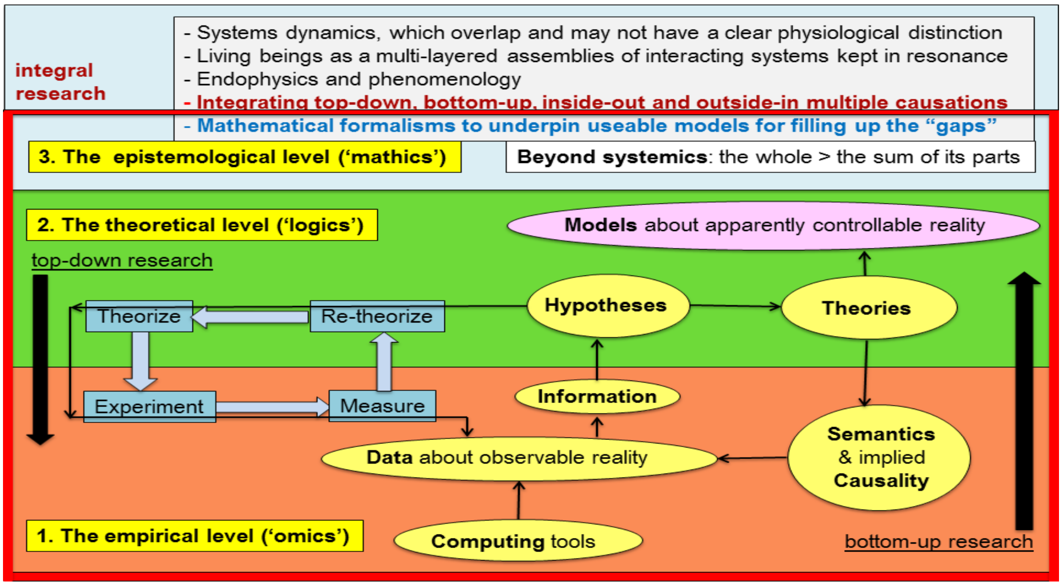

Fig. 1: *Methodologies for research in life sciences*

The challenge to translate the holistic Eastern worldview of a harmonic Universe into scientific models of complex biological systems is well known. Denis Noble has hosted prominent work on defining the problem [106-108, 12]. On the one hand we have complex signaling networks in living systems balanced at multiple levels from molecules through cells and tissues to organ(ism)s and (eco)systems that need to be adequately comprehended to solve severe problems such as developmental and epigenetic disorders, cancer, autoimmune diseases, limiting and extirpating a virus outbreak, etc. On the other hand we have multiple specialized disciplines and dedicated practitioners, dealing with these issues without sufficient background in mathematics[3] and informational interrelationships. This is certainly insufficient to bring down new theories to everyday practice easily and investigate in silico highly abstract theoretical models and hypotheses. Instead, ad hoc empirical studies keep dominating the research landscape, thus letting classical inductive system biological and bioinformatics methods be the single source for models derived from extracted fragments of knowledge out of big data analyses that passed statistical thresholds.

Integral Biomathics was proposed as a unifying framework for both top-down and bottom-up research methodology initiated at the third level and overarching the other two levels with the red square frame on Fig. 1 while expanding it inside out [63, 7, 11, 1-5, 10, 12]. This program collects the viewpoints of leading scientists, mathematicians and philosophers to approaches beyond the current state of the art, for devising a new paradigm for theoretical research in biomedical sciences towards defining a unified theory of life, [122-124, 134-139, 196-199]. Three large volumes constitute the collected current state of the art in the field [1, 2, 3]. The present special issue including this article is another step towards this goal.

Integral Biomathics considers itself as continuation and extension of the research line traced by Rashevsky [15-20], Waddington-Goodwin [21-23], Varela-Maturana-Uribe [24], Rosen-Louie [25-31] and others [39-42]. Its core insight is that the clue to understanding living systems is their structured development as 'organic' multi-level complexes, captured by means of *appropriate* biomathematical and biocomputational formalisms. This means that using the latter should not be seen as an end in itself. Our goal is to address truly eligible applications of mathematics and computation to biology. In other words, we are looking for those *patterns* in biology – called diagrams in mathematics – that can be informed by mathematics and computation while preserving the empirically observed relationships between the elements at many different levels all throughout these modelling transformations.

[3] Deriving a theory from data – induction – "is not a valid method for scientific proof" ([84], Preface).

However, It is not just a matter of making higher mathematics and theoretical computer science available for studying biology in a new way. It is a matter of finding just what (and which) kinds of them fit in the problem descriptions and help solving them[4]. Using Integral Biomathics is substantially different from the methods used in systems biology today [10, 12, 32-34]. Our approach includes not only the relational [25-31, 15-16], but also the *experienced*, first-person aspect of the phenomenological philosophy of Brentano [35], William James [36], Husserl [37], Heidegger [38] and above all – Merleau-Ponty [88-90]. Particularly, the relation of Category Theory to phenomenology was explored in [44]. The previous efforts of our research coalesced on: i) the central importance of novel biology-driven mathematical and computational models of *dynamic multilevel complex systems* that sufficiently well match the “exo” and “endo” phenomena at hand, [43]: organisms, their conglomerations and internal processes of development and disease, and ii) the key role of *timing and synchronization* in biology characterized by the requirements for a new, integral notion of time for living systems [96-97, 78, 62, 53] which includes also retrocausality [60-62] the phenomenological, first-person aspect of time [37-38, 21-23, 98-99, 102, 104]. In this context the authors have proposed a formal biomathematical and biocomputational research framework WLIMES [6], based on the complementary synergy between a non-axiomatic (i.e. “rigid but flexible”, [75]) situation and context aware spatiotemporal logic, WLI [8, 9], and the methodology MES [13,14], based on a dynamic category theory for multi-level, multi-agents and multi-temporality complex systems such as living systems.

The aim of this paper is to emphasize some resonances between Integral Biomathics and Eastern philosophies on the specific example of WLIMES. In particular, this will be provided through the careful examination of the main principles and characteristics of, successively, MES, WLI and WLIMES. Let us note that, in the past, CT has been criticized for its limited capability to model emergent and quantum phenomena in living systems using organizational closures (causal entailments) and modelling relations known from the works of Rashevsky [15-20] and Rosen [25-29] on Relational Biology and (M,R)-systems. Yet recently, CT has made significant progress with new extensions and syntheses suggested, e.g. in the research of Letelier [196], Kineman [197], Louie [30-31] and Longo [198-199], and in particular in the work of A. C. Ehresmann and J.-P. Vanbremeersch [13, 14] later referred in this paper.

2. The Memory Evolutive Systems and their resonances with Eastern thought

MES is a mathematical methodology based on a ‘dynamic’ category theory, which has introduced several categorical notions (Hierarchical Evolutive System, Multiplicity Principle, Complexification process, Landscape of a coregulator) to adapt to the properties of multi-level multi-agents, multi-temporality ‘living’ systems[5]. Here we essentially discuss the relations between these concepts and some characteristics of the Eastern philosophy. However, we are aware of the risk of abusing interpretations when comparing rigorous mathematical definitions to more intuitive and metaphorical verbal notions.

2.1. Category Theory is an ‘organic’ mathematics

«While European philosophy tended to find reality in substance, Chinese philosophy tended to find it in relation.»

— J. Needham, p. 68-69, [119]

«In contrast to the [classical] mechanistic Western view, the Eastern view of the world is ‘organic’. For the Eastern mystic, all things and events perceived by the senses are interrelated, connected, and are but different aspects or manifestations of the same ultimate reality.»

— Capra, p. 22, [105]

[4] We should keep in mind that there are also incomputable branches of physics and biology, e.g. [80].

[5] For precise definitions, we refer to the 2007 book by Ehresmann and Vanbremeersch, [14].

Usually mathematics study specific ‘objects’, such as numbers, lines, groups, topologies, etc. It is different in Category Theory (CT), [45-46, 87], a formal domain of mathematics introduced in 1945 by Eilenberg and MacLane [109], at the frontier between mathematics, logic and meta-mathematics. CT provides conceptual tools to mobilise and manage ideas regarding mathematical structures. There have been a number of philosophical analyses, discussions and reflections on the role Category Theory could play in Mathematics (e.g., [112; 113]) and in the Sciences. Charles Ehresmann stresses its unifying role, explaining that: *« without a unifying theory following a period of rapid expansion, the mathematicians would fatally tend to use divergent, incompatible languages* » … *« this theory of categories seems to be the most characteristic unifying trend in present day Mathematics* », [114, pp. 4-5].

Let us recall that a *category* is a directed (multi-)*graph* with a supplementary structure, namely an internal composition law associating to each path[6] of the graph from A to B, a unique arrow from A to B called its composite. This law is associative and admits identities. A vertex of the graph is called an *object* and an arrow is called a *morphism*[7]. Categories are ubiquitous in Mathematics. There are two major classes of them:

i. ‘small’ (simple) categories such as monoids (or groups) which are categories with a unique object; or categories associated to preordered sets which have at most one morphism between two objects, and
ii. ‘large’ (composite) categories such as *Set* (the category of sets) in which the objects are (small) sets and the morphisms are maps between them; or categories of structured sets, e.g. the category of groups, of rings, of topological spaces, of graphs, etc., with the adequate variety of morphisms between them; and even the category of categories *Cat* with objects the small categories and morphisms the *functors* between them.

Category Theory is well in phase with the Eastern philosophy, since it is a 'relational’ mathematics [110-111], which emphasizes the relations between objects rather than the structure of the objects themselves. Indeed, an object A of a category **C** is *characterized in* **C** not by its 'ontological structure' but *by the set of morphisms arriving* to it, which correspond to the different operations (functions) in which it participates. (More precisely, the Yoneda Lemma asserts that two objects A and B of a category **C** are isomorphic[8] if and only if the functors Hom(A,-) and Hom(B, -) from **C** to **Sets** are equivalent). Thus, a given category **C**, looked at as an entity by itself, represents a particular ‘organic world’. This organicity is limited to **C** since an object A of **C** can also be an object of another category **C’** in which it acquires another characterization through the morphisms in **C’**.

2.2. A hierarchical category as “a hierarchy of wholes”

« La représentation que les Chinois se font de l’Univers <…> s’inspire de l’idée que le Tout se distribue en groupements hiérarchisés où il se retrouve entièrement. »

— Granet, [180], p. 199

«The key word in Chinese thought is order, and above all pattern. »

— Needham, [119], p. 281

«The generic principle of relationality is central to holism and to understanding the Eastern archetype. The focus is upon the whole as a system of related parts. »

— Lowe, [120], p. 8

A living organism, from molecules, cells up to tissues, organs and systems has an ordered internal multi-level organization, in which a component of a given level has itself an internal decomposition into a *pattern* of inter-related components of lower levels which it ‘binds’ into a ‘whole’, e.g. a cell has a molecular decomposition.

[6] A path of a graph from A to B is a sequence of successive arrows linking A to B.

[7] a structure-preserving map from one mathematical structure to another

[8] Two mathematical objects are *isomorphic* if an isomorphism (functional mapping between them) exists and is bijective.

In a category **C,** a *pattern* P is represented by a diagram[9]. The *colimit*[10] operation [86] allows constructing a "*whole as a system of related parts"*, namely binding a pattern P into a unique object, its colimit cP. The 'universal property' of the colimit cP means that, for each object A of **C,** the colimit cP has the same functional role on A as the pattern P operating collectively on A. Therefore, both the colimit and the pattern P are evenly related to all the objects of the category (whence the term 'universal'). The colimit also solves the *Binding Problem* raised by Aristotle: how to bind simple interacting objects together to build "*a whole that is something else than the sum of its parts*"?

Now that we have translated the notions of a pattern and of its 'whole' (or colimit) in a category **C**, we can define a "hierarchy of wholes" representing a multi-level organization of **C**. This leads to the notion of a *hierarchical category* (introduced in [13]): it is a category in which the set of objects is divided into a number of increasing '*complexity levels*' (from 0 to m), so that an object C of level *n*+1 is the colimit of at least one pattern of interconnected objects of lower levels.

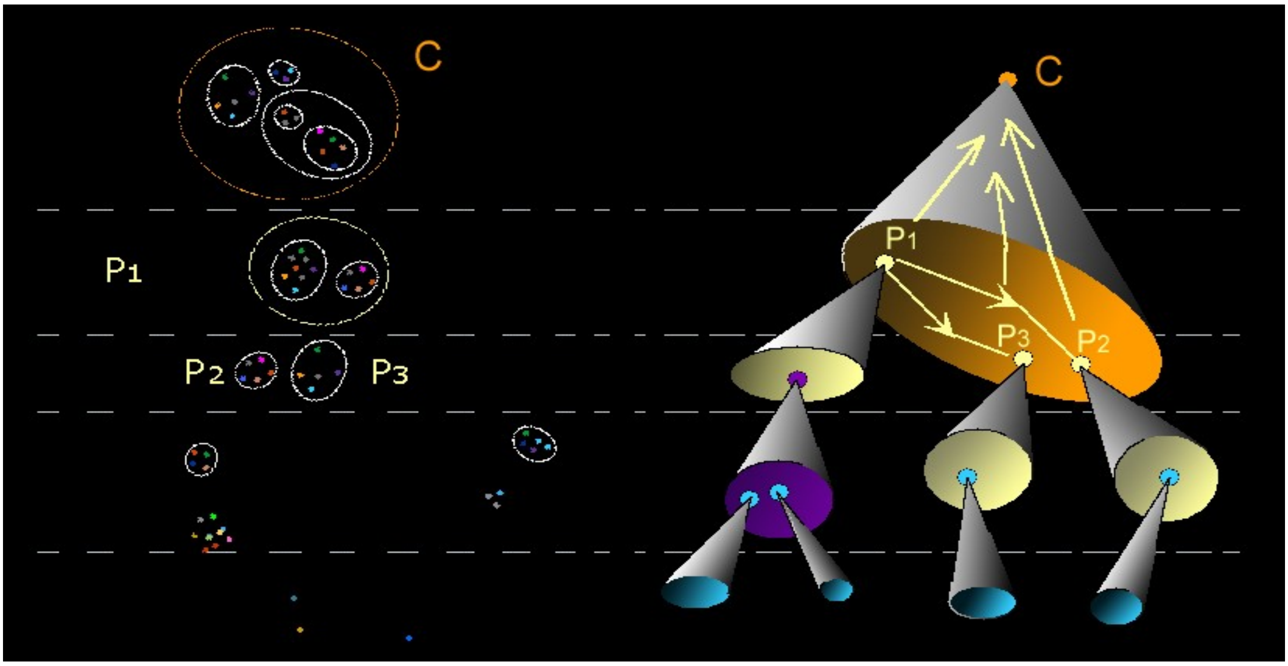

Fig. 2: *The Hierarchy (Holoarchy, [121]) of Components in Category Theory*
(The system S at moment t is represented by a hierarchical category:
objects = components at t; links = channels for their interactions.
Objects are divided into levels so that C of level n+1 has an internal organization into a pattern P of linked components of lower levels, which it 'binds' so that C and P have the same functional role. C is modeled by the colimit of P.)

In a hierarchical category **H**, an object C of level n+1 is called a 'holon' (representing alternatively a part of or the whole itself), i.e. "a double-faced Janus"[11] [121], with respect to the objects of its lower level decompositions; and it is 'simple' with respect to an object of level n+2 if it belongs to a decomposition of this object. C admits also at least one ramification[12] down to level 0 (cf. Figure 2). The *order of complexity* of C is the shortest length of its ramifications.

[9] A *pattern* (or *diagram)* P in a category **C** is a family of objects P_i of **C** and some given morphisms of **C** between them. A *cone* (or *collected link*) from P to an object A is a family of morphisms (maps) f_i from P_i to A commuting with the given morphisms; there may exist several such cones (or none).

[10] A pattern P admits a *colimit* cP if there exists a cone (c_i) from P to cP satisfying the *universal property*: any cone (f_i) from P to any A factors uniquely through (c_i), in the sense that there is a unique *f* from cP to A such that $c_i f = fi$ for each *i.*

[11] called "aumakua" in Hawaiian or a "totem" in native Americans mythologies with the meaning of a family/clan/tribe spirit.

[12] A *ramification* of C consists of a decomposition P of C, then of a decomposition of each Pi of P, and so on down to patterns of level 0.

2.3. An Evolutive System for "transformation and change"

« In the transformation and growth of all things, every bud and feature has its proper form. In this we have their gradual maturing and decay, the constant flow of transformation and change. »

— Zhuangzi, Chuang Tzu, [181]

« The Chinese sages saw the world in terms of flow and change, and thus gave the idea of a cosmic order an essentially dynamic connotation[13]*.* »

— Capra, p. 188, [105]

A living system has interacting components, which vary over time. There are global 'structural transformations' such as suppression, addition or combination of components, but also more or less smooth 'dynamic changes' in the components themselves. For taking the structural transformations into account the system cannot be modelled by a unique category, and the dynamic change requires accounting for the "flow of time" during the life of the system. Moreover both the structural and dynamic changes have to be coordinated.

> ***Remark 1****: Through "Returning is the motion of the Tao" (Lao Tzu, [126]), on the short term of life of a living system, we can approach its timeline by a linear total order. In MES, other kinds of temporality will be introduced (cf. Section 2.6).*

To account for both kinds of changes, the system is modelled by a *(Hierarchical) Evolutive System*, consisting of:

(i) its timeline T modelled by a (discrete or continuous) part T of **R**;

(ii) for each t of T a (hierarchical) category Ht having for objects the 'dynamic' states at t (e.g. the activity) of the various components existing at t, and for morphisms — the states of the interactions between them (e.g., their propagation delay, energy, etc.) existing at t;

(iii) the change of configuration from t to a later time t' is represented by a partial functor 'transition' from Ht to Ht' satisfying a transitivity condition[14].

A *component* of the system is then modelled by a maximal family of objects of the configuration categories (its successive states) related by transitions. Similarly, we define a *link* between components as a maximal family of morphisms related by transitions; a link is *active* (meaning: transferring information) or not at t and has a *propagation delay* (for transferring the information). Both components and links are 'dynamic', i.e. always changing, entities.

2.4. Multifaceted components as "dynamic patterns"

«This notion of dynamic balance is essential to the way in which the unity of opposites is experienced in Eastern mysticism. It is never a static identity, but always a dynamic interplay between two extremes » … *«The basic elements of the universe are dynamic patterns; transitory stages in the 'constant flow of transformation and change', as Chuang Tzu calls it.* »

— Capra, p. 146 and p. 202, [105].

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[13] "The whole emerges simultaneously with the accumulation of the parts, not because it is sum of the parts, but because it is immanent within them." (philosopher Henri Bortoft (1996) on Goethe's understanding of morphogenesis and his way of seeing the unity of all natural phenomena in contrast to the one of reductionist Newtonian science, [183], p. 126; citation referred to by Irwin and Baxter (2008) while paying tribute to Goethe's contribution to science for the development of a rigorous phenomenological method for training imagination as a scientific tool for cognizing the world (p.132, [184]). The influence of Eastern thought on Goethe's work, (e.g. *Faust*, Part Two, Act V, p. 270: "I'd rather have Eternal Emptiness", [185]) e.g. through the philosophy of Schopenhauer [186] is well documented, (cf. Section 3.5). This is a field for further research in modeling both natural and synthetic life systems.

[14] More generally, a (*Hierarchical) Evolutive system* is defined by a functor from the category associated to a total order (here — the order induced on T by **R)** to the category of (hierarchical) categories and partial functors between them. It is hierarchical if the categories Ht are hierarchical.

A component C of a living system is not a "static identity" but a "dynamic entity" which preserves its own individuation during its life, in spite of the progressive change of its lower level pattern decompositions; e.g., a cell keeps its identity though renewing its molecules in time (Matsuno, [97], has emphasized this "class/identity" difference).

Among the components, there are components, which we call *multifaceted*; they have, simultaneously or not, structurally different lower level pattern decompositions between which they can "balance" (or switch[15]), while keeping their identity as a "whole". This is a consequence of the "degeneracy property" of neural and biological systems, emphasized by Edelman: *"degeneracy, the ability of elements that are structurally different to perform the same function or yield the same output"* [122].

In a hierarchical category, an object is *n-multifaceted* if it is the colimit of at least 2 patterns contained in the levels ≤ n, which are non-isomorphic and not *structurally connected*[16]. The category is said to satisfy the *Multiplicity Principle* (MP) if it admits n-multifaceted objects for each n > 0. In a Hierarchical Evolutive System, we suppose that the configuration categories verify MP. Then there are *n-multifaceted* components. Such a component has also different not-structurally connected ramifications between which it can balance. Over time it may lose some ramifications and/or acquire new ones, up to its own destruction. The existence of such multifaceted components gives more flexibility to the system. In particular it allows for the development of a robust though flexible and plastic memory.

Among the links from a component A to a component B, we have *n-simple links* which bind together a cluster of links between lower level decompositions of A and B; such a link is entirely known through the cluster it binds. A consequence of MP is the existence of composites of n-simple links, which bind nonadjacent clusters separated by a switch (see Fig. 3) and are not simple. Such *complex links* represent emergent properties at a level n+1, not observable at levels ≤ n, although dependent on the global structure of these levels.

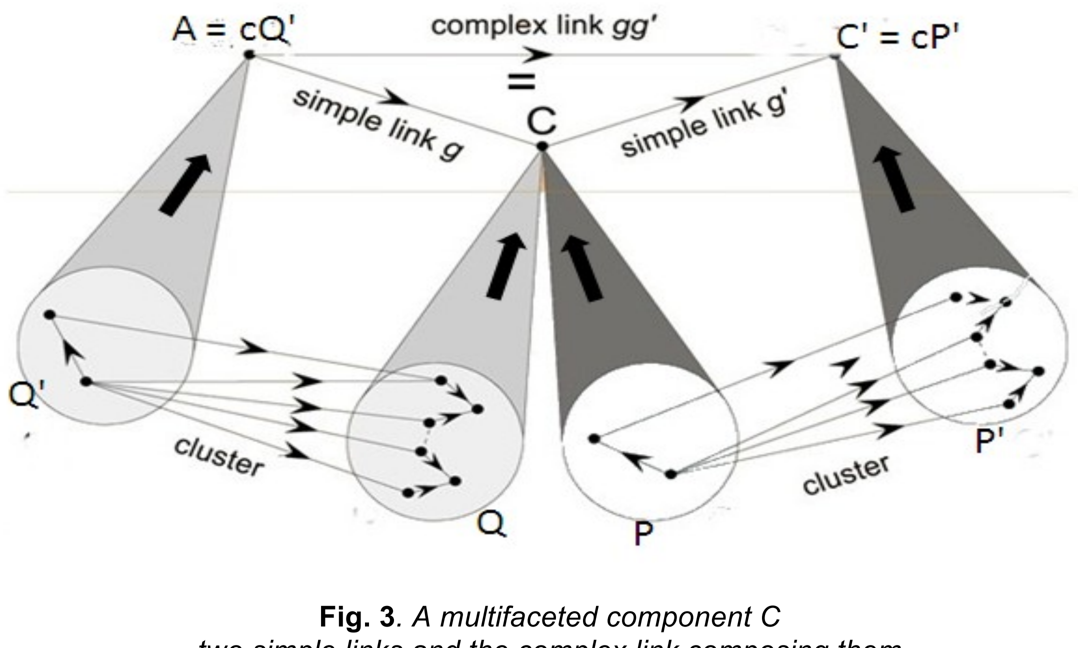

Fig. 3. *A multifaceted component C two simple links and the complex link composing them*

[15] The switch (or balance) between non-structurally connected decompositions of a multifaceted component could be responsible for Cherdantsev's „oscillations", [212].

[16] Two patterns P and Q with the same colimit C are *structurally connected* if they are isomorphic or if there is a cluster of links between P and Q binding into the identity of C.

2.5. Emergence through the Complexification[17] Process

«The processes of alternating aggregation and dispersion as one of the main causes of the coming-into-being and the passing-away of material and living things. »

— Needham, p. 444, [119]

In a living system, the structural transformations are of the following three kinds: i) 'adding' new elements, ii) 'suppressing' or 'dissolving' some components, iii) combining some given patterns (so that they acquire a colimit) to form more complex 'wholes'.

Given a procedure Pr with objectives of the above kinds on a category H verifying MP, the c*omplexification process* for Pr consists in constructing a category in which these objectives are optimally satisfied. The complexification of H for Pr has been explicitly constructed[18] [13] (cf. Fig. 4). It leads to the emergence of *complex links,* which represent emergent properties, e.g. introducing "change in the conditions of change", [125]. Thence,

> **THE EMERGENCE THEOREM** [13]. *In a category satisfying MP, the complexification process may lead to the emergence of multifaceted components of increasing complexity orders connected by complex links. These complex links render unpredictable the result of iterated complexifications.*

In a Hierarchical Evolutive System (HES), the transitions between configurations result from both structural transformations and dynamic change of the components. The structural transformations are modelled by (iterated) complexifications. However, the selection of a procedure (e.g., by internal agents, cf. 2.6) is constrained by the need that the corresponding complexification induces a coherent change in the dynamic states of the components and their links. Thus only some procedures "are enabled", [123].

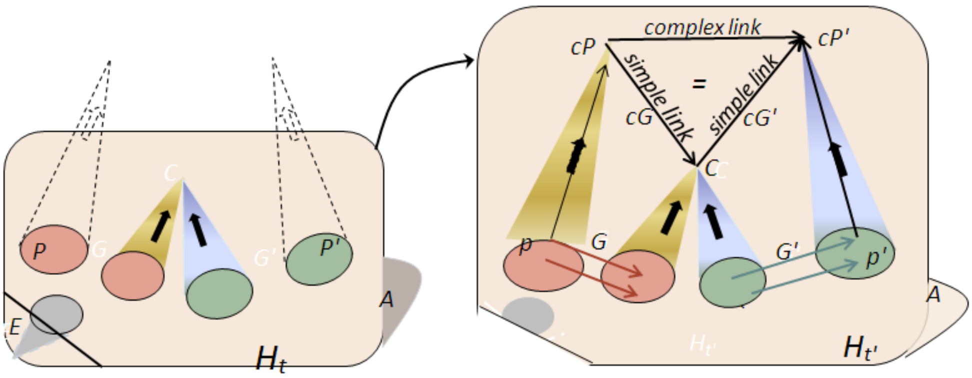

Figure 4. *Construction of the complexification Ht' of Ht:*
The patterns P and P' acquire colimits cP and cP',
The clusters G and G' bind into simple links cG and cG',
A complex link from cP to cP' emerges as the composite cG' cG

As we have done it, the construction of the complexification introduces entirely new components, and thus is compatible with Kauffman's idea of an "open universe" [124]. However such a universe is not compatible with the Eastern vision:

«The universe itself is a vast organism, with now one, and now another component taking the lead» … «all the parts of it collaborating in a mutual service. »

— Needham, p. 288-289, [119]

[17] The term "complexification" here is not taken in the Lamarckian sense as direct adaptability, but refers to a well-known mathematical construction, which is recalled in this section and plays an important role in the sequel.

[18] The complexification of H for Pr is defined as follows: it has for objects the objects of H, which are not suppressed by Pr and, for each pattern P to bind — a new object cP which will be 'forced' (through recurrent processes) to become its colimit in the complexification. Among the new morphisms between complex components, we have not only *simple links* but also complex links (because of MP).

To agree with this vision, we may suppose that the "universe" is represented by a large topos in the sense of Lawvere-Tierney [115] (as Graves and Blaine do with Algos [116-118]), let us call it **W**, and that the configurations are all subcategories of **W**. Then the successive complexifications can be done "internally to **W**" (that is possible since in a topos each pattern admits a colimit).

2.6. MES *as a "multi-level self-organising 'living' system"*[19]

« The harmonious cooperation of all beings arose not from the order of a superior authority external to themselves, but from the fact that they were all parts in a hierarchy of wholes forming a cosmic pattern, and that they obeyed the internal dictates of their whole nature. »

— Needham, p. 582, [119]

The overall dynamic of a living system weaves the different internal local dynamics of its processing agents, called *co-regulators* (CRs), each operating with its own discrete time-scale; the dualism local/global is mediated through recourse to a developing flexible memory making it able to learn and adapt. It is modeled by a *Memory Evolutive System* (MES), which is a Hierarchical Evolutive System equipped with a hierarchical evolutive subsystem, the Memory, and a net of Evolutive subsystems, modeling the co-regulators.

(i) *The Memory to store "constant patterns"*

« The Chinese …. not only believed that flow and change were the essential features of nature, but also that there are constant patterns in these changes …. The sage recognizes these patterns and directs his actions according to them. »

— Capra, p. 105, [105]

The (long-term) *memory* stores knowledge of any kind, including implicit memories such as automatic processes, procedures with their commands to effectors. Its dynamic multifaceted components can be recalled under any of their multiple ramifications to recognize the memorized item under different forms, and they adapt to changing situations by acquiring new ramifications and suppressing those which are no more valid.

The memory develops over time by formation of multifaceted components of increasing complexity order through iterated complexification processes; this development is a consequence of the Emergence Theorem, which, thanks to the MP, also implies that the memory is both robust and flexible.

(ii) *The net of co-regulators*

« Eastern way of thinking rather consists in a … multi-dimensional impression formed from the superimposition of single impressions from different points of view. »

— Lama Govinda, quoted by Paul Reps, in [187], p. 104

A MES has also a network of internal agents, called co-regulators, which have "different points of view" on the system. A *co-regulator* (CR) is an evolutive subsystem of the MES with its own function, complexity level, and rhythm. The co-regulators do not form a hierarchy but a heterarchy: a CR of level n does not aggregate lower level co-regulators though it might send commands to them. CR operates as a hybrid system, [188], with its own discrete time-scale delimiting its successive steps on the continuous time-scale of the system. At each step, the information received by CR via the active links arriving to it during the step is processed in the *landscape* of CR at the moment t, which is modeled by an Evolutive System having those links for components.

[19] cf. [120]

Using the memory, an adapted procedure Pr is selected on it, and the corresponding commands are sent to effectors; that starts a dynamical process whose result will be evaluated at the beginning of the next step; if the objectives are not attained, we have a *fracture* for CR. A main cause of fractures is the non-respect of the *synchronicity laws,* which a CR must respect (they relate the length of a step with the propagation delays and stability spans of the components of the landscape; cf. [14], chapter 7).

(iii) *The global dynamic*

«An experience of higher dimensionality is achieved by integration of experiences of different centres and levels of consciousness. »

— Lama Govinda, quoted by J. Needham, p. 582, [119]

The global dynamic results from the interplay among the co-regulators to harmonize their different procedures with risk of fractures for some co-regulators. At a given time, the interplay is realized through the competition between the commands sent to effectors by the procedures of the different CRs. Its flexibility comes from the MP allowing for processing each command along its most adapted ramification. The problem is complicated by the fact that the different co-regulators have very different rhythms, which leads to a 'dialectics' between a short-rhythm co-regulator and a long-rhythm one.

3. The Wandering Logic Intelligence and its resonance with Eastern thought

WLI is a bio-inspired computational theory, which was initially used for designing active self-organizing mobile networks based on ad hoc situation and context based knowledge acquisition and examination using temporal logic (s. [39-40], [91-92]). We have suggested that it can be adopted also for the formal modelling of both synthetic and artificial life systems. In the following, we discuss the relation between the basic WLI concepts[20] and those of Eastern philosophy.

3.1. The Wandering Logic Intelligence as a 'living system' model

An essential characteristic of the WLI model is its inherent ability to instantly spread out a pair (tuple) of data and associated instructions, operands and operators (objects and arrows, or categories and functors) about structural changes among the individual elements of a communication network by encoding 'genetic' instructions for migrating and replicating these structures via active information packets – as network genes, called "N-genes" [8, 39], (Fig. 5).

The latter represent the functional analogy with a living system while being primarily focused on implementing the concepts of virtual communication infrastructures, information encoding and context-based exchange between the participants. Thus WLI represents an evolving network architecture which is composed of dynamically reconfigurable network elements (called "netbots" or "ships") generating and exchanging information about themselves and their surrounding environment (close neighborhood or "local landscape") by means of active information packets (called "shuttles") containing data and executable code to process them packed in the form of n-genes. In a Wandering Network (WN) shuttles are used for signaling and transporting various kinds of information (physical, algorithmic, topological, etc.). Initially, temporality in WLI has been modeled as external linear clock time. Netbots in WLI do not exhibit an explicit hierarchy. They can be also heterarchical [68, 71]. Their landscapes at a *given instant of time* demonstrate a temporarily available internal composite hierarchy of structures and functions of their building elements interlinked with other elements and groups of them, including elements inside them.

[20] For detailed definitions and explanations we refer to the 2002 dissertation of Simeonov, [9].

This composite hierarchy is changed stepwise by that outcome of processing the shuttle information in combination with other internal and external exchange within the individual netbots and other components of the system. Herewith, the six WLI principles (*Dualistic Congruence, Self-Reference, Multidimensional Feedback, Pulsating Metamorphosis, Resource Availability and Utilization, Second-Order and Higher-Order Logic*) define the overall development of the network infrastructure, or the living organ(ism) in a biomedical context.

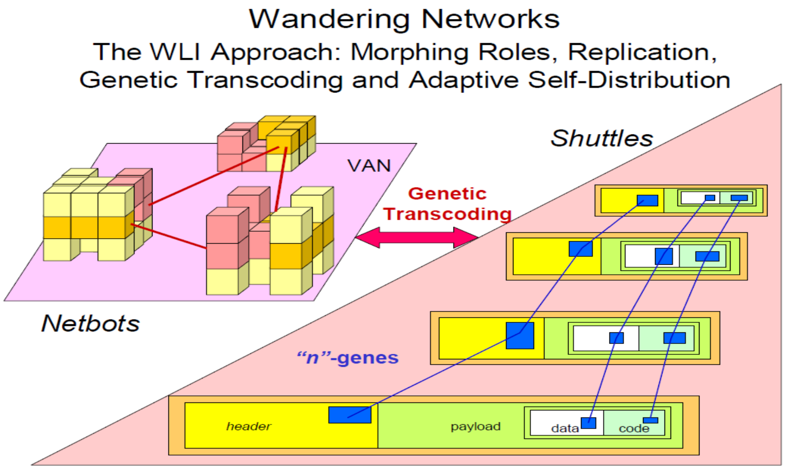

Fig. 5: *The Wandering Network as an "n"-geneered evolution of virtual infrastructures*

The last, sixth principle of *Second-Order and Higher-Order Logic* was added recently to capture newer developments [76, 77, 49, 50, 51, 53, 78, 79]. It is related to the logic at work inside the system, i.e. between the particular hierarchical levels, which does not necessarily obey a binary law (e.g. multivalued and intuitionistic logic). Instead, there is a new kind of reasoning, which successively turns the preceding predicate of an expression at a distinct level of hierarchy into the succeeding subject of the expression at the next level, thus allowing for additional quantifications of the individual levels. In this way we observe a sort of bottom-up gradient in the flexibility of the logic from the elementary physicochemical level to the behavioral level of an organism. In this paper, however, we regard the meaning of Second-Order and Higher-Order Logic in a broader conceptual context (s. Section 3.7).

In summary, a WLI realization implies a multiplicity of evolving network gates, which can be regarded as an abstraction of an ecology system of living organisms maintaining its equilibrium. By definition the WLI nodes/gates cooperate to realize a self-stabilizing network architecture. However, they can also compete for a resource/function by involving some special reservation policies based on monitoring their shuttle traffic. The following sections present a glimpse into the extended relation of the WLI's formal model foundations to some major concepts in Eastern philosophy.

3.2 The First Principle: Dualistic Congruence (Polarity[21])

«The Way produces one, one produces two… All things submit to yin and embrace yang.»

— Lao Tzu, Chapter 42, [126]

«Possibly the concept of duality is Zoroastrianism's greatest contribution to modern civilization, manifesting itself in the manifold areas of human knowledge.»

— Cyrous, p. 995, [129]

[21] see the third citation below of Lama Anagarika Govinda.

«The difference between dualism and polarity is that dualism sees only the irreconcilable opposites and leads to prejudiced evaluations and decisions which sunder the world into equally irreducible opposites; whereas polarity is born of unity and includes the concept of wholeness: the poles are complementary to each other, are indissolubly involved in each other, like the positive and negative poles of a magnet, which imply each other and cannot be separated. »

— Lama Anagarika Govinda in his introduction to [201], p.22, 31. January 1973

The second citation was selected because Western civilization was influenced by the Persian tradition already in antiquity. But this concept is present in almost any culture around the Globe. In India, the concepts of unity and duality (multiplicity) go back to the earliest Upanishads (3500 – 2100 BCE), [178], which could have been adopted by Zoroastrianism (1000 – 588 BCE), [179], in Persia. It is however the contribution of the latter to introduce them to the Greeks, presumably after the conquests of Alexander in Asia, along with other Eastern teachings such as the bivalent logic that could have influenced Aristotle to build a system for reasoning based exclusively on binary oppositions. We still use this mode of thinking and inadvertently reinforce it through bringing to perfection our technology and research methods based on this logic up to the present. It is interesting to note that Plato in the dialogue "Parmenides" introduced a different idea of the One that generates the Many when it becomes "The Existing One" and developed a logic of dualistic congruence (polarity), not dualism, that elevated him to the level of Lao Tzu of the West.

Hence, the second citation refers to a different kind of duality from this understood by Eastern thinkers in the first and third ones: the common *dualism of contrasts/opposites*. In particular, the Taoists recognized that oppositions could be non-exclusive and bound together, originating from the same source and only existing in relation to each other. This is another motive for closer examination of Asian thought. Some Western thinkers (Anaximander, Heraclitus, and post-Kantians as Fichte, Schelling, Hegel, Kierkegaard, Peirce and Nietzsche) have also realized such deeper, underlying reality, but they have been indulged to reconciling it with the prevailing Aristotelian paradigm of discrete categories. But the successors of the ancient Persian traditions of Zorotastrianism and more specifically – Manicheism (210 – 276 ADE) and Mazdakizm (500 – 800 ADE), known for their dualistic cosmology/theology of *Light* (the good one) and *Darkness* (the evil one), evolved in the Middle Ages through the works of such bright minds as Ibn Sina known as Avicenna (Avicennaism), Sufi Shahab al-Din Suhrawardi (Illuminationism) and Sadr al-Din al-Shirazi (Transcendent Theosophy) and led to post-Aristotelian reasoning systems such as hypothetical syllogism, temporal modal logic and inductive logic. In modern days we are witnessing more revolutionary thinking of Persian origin with Lofti Zadeh's fuzzy set theory [163], fuzzy logic [164] and fuzzy logic systems [165] up to technological innovations like natural computation based on words [166]. Therefore, Persian philosophy plays an important mediating role between East and West thinking, which one day, if given a chance, may trigger the development of more practical vague and blurry reasoning systems, closer to Zen Buddhism (Buddhism modified by Taoism) and the manifestations of natural life (s. Section 3.7).

The WLI *Dualistic Congruence (or Polarity) Principle* (DCP) has its closest analogy in Chinese philosophy in the universal pair of opposite, polar, but complementary and each other implying forces *Yin* and *Yang* – the negative/passive/female vs. positive/active/male – which are interconnected, and interdependent giving rise to each other as they interact, (Fig. 6). This duality of natural forces has been the foundation for traditional Chinese science, philosophy and the humanities represented by policy, medicine and the martial arts (taiji-quan and qi-gong) since Yellow Emperor's Classic of Medicine (dated back to 2600 BCE) to present days. The concept of dualistic congruence (polarity) lies in the foundations of Taoist metaphysics [126], as a moral category in the ethics of Confucianism [127], and prominently as a building element of the 64 "oracle hexagrams" (King Wen divination sequences) in the classical "Book of Changes" ("I Ching" or "I Ging") known as the cosmological text "Ten Wings" (Kern, p. 17, [128]). According to Needham [119] they should be considered along with the Five Elements as foundations of the School of Naturalists, which lay "at a deeper level in Nature", as the "most ultimate principles of which the ancient Chinese could conceive".

Modern research could learn and benefit a lot from using this principle to unfold a truly integrative and relational science similarly to Category Theory and its later derivatives did for mathematics. The remaining tough question to be answered is: *How can we express this unconventional mode of thinking about "simultaneously allowable opposites" in terms of our conventional mathematical reasoning and computational tools based on binary logic?*

Perhaps the analogy with the superposition principle in quantum mechanics [200] could provide a *partial*[22] solution for this dilemma, but QM has other worries now, [203]. Therefore, we could try addressing the above key question with a modified version of Schrödinger's cat paradox at the expense of allowing bivalent logic. We could consider[23] opposites allowable

- 'simultaneously' in the same time, but disparate in space, or
- 'simultaneously' in the space, but disparate in time.

Example: Cats are very territory aware creatures. Yet, they are forced to share territory at least in UK cities where every second house has a cat. In order to avoid fighting with each other, cats precisely anticipate [58-59] and share space and time in such a manner that they rarely meet.

So, why not splitting space-time into mundane space and time when measuring at the quantum level?

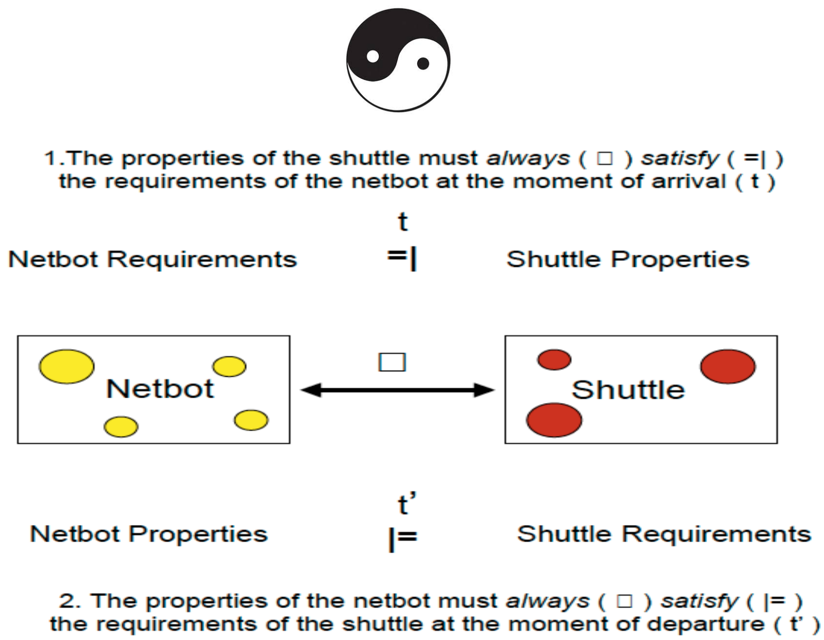

Fig. 6: *The WLI Dualistic Congruence Principle*
in temporal logic: i) the shuttle properties at moment t must always fulfill the netbot requirements; ii) the netbot properties at another moment t' must always fulfill the shuttle requirements.

Another bothersome issue in modern quantum mechanics is e.g. the conclusion from the delayed-choice experiment of John Wheeler [204-205] recently tested[24]: *at the quantum level reality does not exist until it is measured*. The question is how to comprehend this in the case of interferences of quantum particles, e.g., photons, between two beam-splitters separated even over a distance of a few light years. Although the Eastern sages may remain silent on this issue, the "unity of opposites" can be constantly updated while being the subject of delayed interventions, such as e.g. the insertion or deletion of the beam-splitter nearest to the experimenter at the very last moment.

[22] personal correspondence withj Yukio Gunji, May 9th, 2017.
[23] personal correspondence with Andy Adamatzky, May 8th, 2017.
[24] cf. https://phys.org/news/2015-05-quantum-theory-weirdness.html.

But this choice measurement is *retro-causal*[25], [62]! Nevertheless, mainstream QM is still hesitant in accepting retro-causality without reservations, and favors instead the convenient time-honored causality. Contemporary science is cautiously advancing by making some compromises, but safeguarding its logical foundations. Its vanguard, modern physics is obviously not an exception. The crisis of science continues [208-210].

The Wandering Logic Intelligence model is based on: a) the dual/polar nature of the *ployons* [8, 9], the active mobile network component abstractions in their two manifestations, *ships* or netbots (active mobile nodes) and *shuttles* (active gene-coded packets), and b) on their congruence. The *Dualistic Congruence Principle* (DCP) states that a ship's architecture reflects the shuttle's structure at some previous step and vice versa. Thus, *ships* are both reconfigurable computing machines and active mobile nodes in terms of hardware and software. Shuttles transport software, which can activate/replace ships and their components/aggregates. A ship processing shuttles can change its state and re-configure its resources and connections *a posteriori* for further actions. In addition, it can adapt (itself) *a priori* to communications to *best-match the structure of the active packets (shuttles) at the time of delivery.* Finally, a ship can change the state of a shuttle. *Shuttles***,** in turn, can be e.g. interpreted by a reconfigurable computing element inside a ship to build and/or invoke new functions. A shuttle approaching a ship can *re-configure itself* becoming a *morphing* packet to provide the desired interface and match a ship's requirements. This operation can be e.g. based on the destination address and on the class of the ship included in this address.

The philosophy behind the WLI is that both netbots/ships and shuttles represent the very same thing, the net. Ultimately, we can pack a network into a shuttle, and then unpack it into another netbot or entire net infrastructure. This is the essence of the Ying-Yang principle. Thus, ships and shuttles reflect the duality of „N-genered“ artefacts, [9], – between thought and device, virtual and real – like systems composed from software and hardware, packets and routers, design drawings and buildings, vehicles and roads, etc. The idea is naturally related to Kauffman's idea that epigenetics converts the genome into a genetic network: "... networks naturally have the property that each cell type can be described in a kind of *combinatorial epigenetic code*. The network has specific number of genetic decision-taking 'circuits', the different independent feedback loops." (p. 481, [167], s. also Section 3.4: Multidimensional Feedback Principle). This kind of intelligent decision-making at the cellular level defended by Ford [161] is probably also taking place in plasmids, small DNA molecules within prokaryotes (bacteria, archaea) and eukaryotes that are physically separated from a chromosomal DNA and can replicate independently.

3.3 The Second Principle: Self-Reference

«And here they say that a person consists of desires. And as is his desire, so is his will; and as is his will, so is his deed; and whatever deed he does, that he will reap. »

— Anonymous, The Upanishads ([130], Brihadâranyaka IV.4.5[26])

«Meditation here is not reflection or any other kind of discursive thinking. It is pure concentration: training the mind to dwell on an interior focus without wandering, until it becomes absorbed in the object of its contemplation. But 'Samadhi' [absorption] does not mean unconsciousness. The outside world may be forgotten, but meditation is a state of intense inner wakefulness. It is consciousness itself, which means that *all* the senses close down. »

— Anonymous, The Upanishads, ([131], pp. 26-27).

[25] personal correspondence with Koichiro Matsuno, May 9th, 2017.

[26] http://www.sacred-texts.com/hin/sbe15/sbe15076.htm.

The following characteristics identify a WLI network as *self-referring*:

1. Each mobile node / ship *knows best*[27] its own architecture and function, as well as *how* and *when* to display it to the external world. Ships are required to be *fair* and *cooperative*[28] w.r.t. the information they display to the external world.

2. Ships, are living entities: they can be born, live and die. They can also self-organize into clusters based on one or more *feedback* mechanisms. Communication among the ships is realized through exchanging programs and data by means of *shuttles,* active packets, which may contain encoded structural information about the ships or parts of the network. This information can be used to maintain the operation of the network as a whole, as well as to invoke desired or necessary changes in the infrastructure via service utilization or components' feedback.

3. Each ship can acquire or *learn* other functions and extend its capabilities through additional components *to fulfill its purpose*, as well as to become a (temporary) aggregation of other mobile nodes with a joint architecture and functionality.

The *Self-Reference Principle (SRP)* originally addresses the *autopoiesis* and autonomy properties of the active network elements. In life sciences it founds its direct application in distinguishing the identity of living organisms, [97, 134]. However, this principle implies a more sophisticated characteristic in the broader context of human involvement. This kind of extended self-reference perceives the knowledge about the Self (Atman) through introspection (meditation) and is understood as the *purposeful action of self-realization*. It is analogous to the concept of *self-consciousness* in the Upanishads, i.e. consciousness of one's own real being, the Brahman (the highest Universal Principle, the immanent Ultimate Reality of the universe) in Vedic philosophy (Vedanta), which goes beyond first-person self-awareness. While self-reference refers only to syntactical circulation of causation, self-consciousness could contain not only syntactical self-reference but also semantical reference to the outside world, called the *frame problem*. Gunji has proposed a model corresponding to self-consciousness, by coupling self-reference with the frame problem, [168-169]. Thus, two problems contract with each other, which can result in a sustainable robust self. Future research in this field should be related to the mathematics and logic of *self-reference* [174, 85, 175-177]. It is hardly conceivable how such sort of intelligence can be achieved by synthetic life systems. But we should not forget that interactive automation systems such as those for flight and vehicle control make use of human purposeful action even today. Future brain-computer interfaces can enable richer capabilities of man-machine systems and unconventional reasoning such as Buddhist and vague logic (s. Section 3.7) and the creation of different kinds of virtual and augmented reality tools stimulating creative imagination.

3.4 The Third Principle: Multidimensional Feedback

«Imagine a multidimensional spider's web in the early morning covered with dew drops. And every dew drop contains the reflection of all the other dew drops. And, in each reflected dew drop, the reflections of all the other dew drops in that reflection. And so ad infinitum. That is the Buddhist conception of the universe in an image. »

— Alan Watts Alan on Indra's Net,
Watts Podcast – Following the Middle Way #3 alanwattspodcast.com

[27] to the extent of self-awareness and self-consciousness

[28] in contrast to co-regulators in MES which are competing; this can be changed to make them both partially cooperative and competitive.

The *Multidimensional Feedback Principle*[29] *(MFP)* is a fundamental characteristic of self-organizing systems. Their behavior is determined by their own *response ability* to external stimuli from their surrounding environment and the diverse areas of systems themselves, which are spatially organized in multiple hierarchical and heterarchical levels with local temporalities synchronized on a global scale. This is how the Third Principle expands the scope of the Second. Yet, it does not need to remain limited to the spatial and temporal [53-57] dimensions we know from physics only.
Multidimensional feedback is seen in a different way in Eastern thought. For instance, according to Hindu Vedic cosmology/theology (Vishnu Purana, Padma Purana, Vayu Purana, Srimad Bhagavatam, [154]), which is often misinterpreted as a kind of mythological organization of the material world, the Earth is merely one of billions of inhabited worlds in the universe. There are millions of such universes, with each one shaped like an egg and composed of 3 spheres (realms of material planets) and 14 planes (worlds or lokas) of (incarnated/realized) *existence*. The latter are divided into 7 higher ones (Vyahrti) and 7 lower ones (Pātāla), defining different stages and durations of development of the living beings, which interact with each other maintaining their own identity and *response-ability* in the causal loop. The above model reminds us of Everett's relative state interpretation of quantum mechanics [156-157], also known as many-worlds or multiverse theory. Indeed, in Marchal's work [171-173], and particularly in his thesis [172] on the many-dreams interpretation of Arithmetic, Everett's main view becomes a theorem in computationalist theology, which relates the Brahman with the Taoist and with the Western antique dream argument. Another way to see multidimensionality and (often dialectic) interconnectedness in Eastern thought is through circular [145] or mutual [151] causality, reflected in by the concept of *Karma* or action in Hinduism as both feedback from the past (lives) and feed forward to the future (lives). This model is tightly interweaved with later Buddhist logic/epistemology [155] (s. Section 3.7) and general system theory [151-153]. A third way to comprehend beyond-spatiotemporal multidimensional interdependency is directly through *multivalent Buddhist logic* (s. Section 3.7). All these options demonstrate how we could relate an extended notion of the MFP abstraction to Eastern teachings about different levels of existence.

3.5 The Fourth Principle: the Pulsating Metamorphosis[30]

«… the essential nature of the Lord [Śiva] is perpetual spanda (creative pulsation). He is never without spanda. »

— Singh, *Spanda Kārikās* [158], p. 10.

«Once upon a time Chuang Chou dreamed that he was a butterfly, a butterfly flitting about happily enjoying himself. He didn't know that he was Chou. Suddenly he awoke and was palpably Chou. He did not know whether he was Chou who had dreamed of being a butterfly or a butterfly dreaming that he was Chou. Now, there must be a difference between Chou and the butterfly. This is called the transformation of things[31]*. »*

— *Chuang Tzu, Wandering on the Way*, Mair (Tr.) 1998, [214], p. xxxix

«Felsen sollten nicht Felsen und Wüssten Wüssten nicht bleiben ... »

— J. Wolfgang von Goethe
Sept. 6th, 1776, Hermannstein / Ilmenau

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29 Indeed, it cannot be separated from the self-reference principle and can be regarded as its extension. While self-reference is regarded as a tool of circular causation, it refers only to unidirectional regression such as substituting whole to a part. This can be illustrated by contraction. Fractals can be made either by contraction or by expansion. Usually a contraction map is used to generate a self-similar structure. If one uses expansion instead of contraction, one can also design a self-similar structure. But there is a problem if both expansion and contraction are used. Since there is no synchronous clock by which one can control expansion and contraction, a pattern to be contracted is inconsistent with a pattern to be expanded. Thus, a pair of expansion and contraction can reveal vagueness and/or evoluvability. Recently Gunji and colleagues implemented a pair of contraction and expansion of information (or probability) by Bayesian and inverse Bayesian inference [170], and consider the minimal device of a living system, an *endo-observer*. This implication is consistent with the multidimensional feedback principle.

30 cf. Section 2.3 with the citation reference to Chuang Tzu.

31 wuhua 物化, closely related to biànhuà 變□, lit. "change change" or "change (esp. in form or character); variation; transformation; metamorphosis; reincarnation", https://en.wikipedia.org/wiki/Bianhua.

The generic process of network self-creation and self-organization is referred to as the WLI *Pulsating Metamorphosis Principle*[32] (PMP), (s. Fig. 7-8, [9]) which postulates that:

1. There are two types of moving network functionality from the center to the periphery and vice versa inside a Wandering Network referred to as *pulsating metamorphosis*: horizontal, or inter-node, and vertical, or intra-node, transition.

2. A net function can be based on one or more facts (events, experiences). The combination of net function and facts is called a *knowledge quantum* (*kq)* in the WLI model. Knowledge quanta are a new type of capsules, which are distributed via shuttles in the Wandering Network. Net functions and facts can be recorded by, stored in and transmitted between the ships. They can be selectively processed inside the ships and distributed throughout the Wandering Network (WN) in an arbitrary manner.

3. Facts have a certain *lifetime* in the Wandering Network, which depends on their clustering inside the ships (knowledge base), as well as from their transmission intensity, or bandwidth ("weight"). As soon as a fact does not reach its frequency threshold, it is deleted to leave space for new facts. Since net functions are based on facts, their lifetime and the lifetime of the corresponding network constellations depends on the facts. Which facts determine the presence of a particular function inside the Wandering Network is defined individually for each function[33]. Through the exchange and generation of new facts, it is possible to modify functions to prolong their lifetime. The lifetime of a knowledge quantum is defined by the lifetime of its network function. A modification of a net function is determined by a new set of knowledge quanta.

4. A net function can emerge on its own (the *autopoiesis* principle) by getting in touch with other net functions (i.e. states and net constellations), facts, user interactions or other transmitted information. This new property of the network is called *network resonance.*

5. Network elements can encode and decode their state in *knowledge quanta*. This mechanism is called *genetic transcoding,* (Fig. 5).

This principle describes the emergence and evolution of network infrastructures through virtualization, transportation and transformation of wandering functions in multiple dimensions (s. Section 3.4) depending on their exploitation, which makes them shrink at certain areas and grow at others. It can be metaphorically related to the "divine creative pulsation", *Spanda Kārikās* [158], and the Kashmir Śaiva texts of the Krama school, ([154], p. 572), in Hindu philosophy.

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[32] This principle can be regarded as an extension of the Third Principle (MFP), and hence of the Second Principle (SRP) both in vertical and horizontal scheme from the center to the periphery and vice versa (s. Fig. 9-10).

[33] In Hinduism the philosophy of *Karma* has a similar structure in the network of Souls. Each Soul is analogous to a node on the network. Connections between Souls take the form of Karma: review note by Alex Hankey.

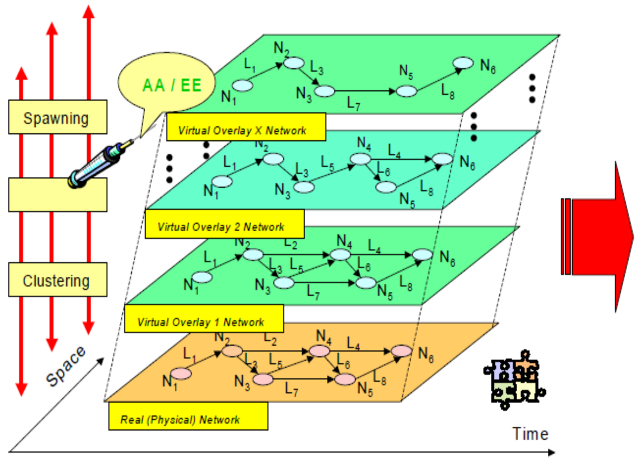

Fig. 7: *Vertical pulsation or network wandering (in-pulsing) — intra-node functional autopoiesis and generated virtual overlay networks over the same physical infrastructure*
Legend: AA: Active Application; EE: Executing Environment: both injected in the infrastructure.

«… 'the supreme principle is the Goddess' who, within the 'Wheel of [the] Twelve Kālīs,' is 'the Abode of the Center (of reality)' in the 'form of the *pulsation of consciousness*,' her 'pulse' marking 'an outward, forward movement . . . and an inward retraction' as

> 'the basis of the four-fold sequence . . . of arising . . ., manifestation . . ., the assimilation of time (*kālagrāsa*), and repose in one's essential nature. . . The other aspect is the form of the Goddess as the Primordial Power (*ādyāśakti*), which generates, sustains and withdraws its manifestations, at one with Herself, and so pulsates with its rhythm. This is said to be that state in which consciousness is swollen like a seed about to generate its sprout.' »
>
> — Dyczkowski, 1992, [159], p.

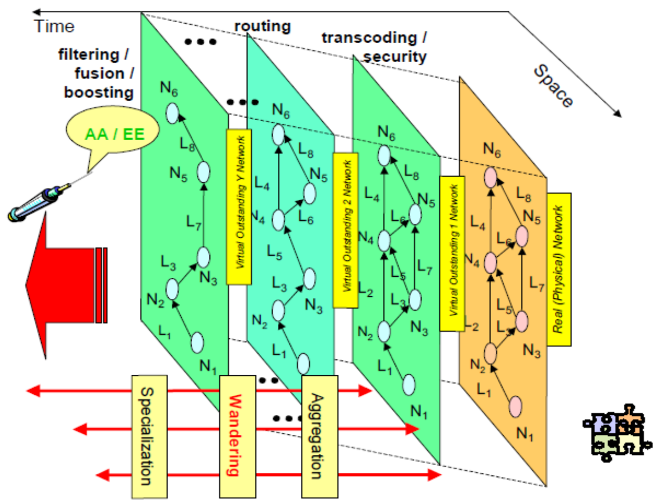

Fig. 8: *Horizontal pulsation or network wandering (ex-pulsing) — inter-node functional autopoiesis and generated virtual outstanding networks over the same physical infrastructure*

The idea behind the above citation is that we should regard this WLI principle as *intelligent process* in the broader context of evolving consciousness rather than as another vitalistic emanation from the past. This is how the Fourth Principle supports the Third Principle (s. Section 3.4).

3.6 The Fifth Principle: Resource Availability and Utilization

> *«Many traditional cultures have viewed this world of experience as being filled with energy, conceived in various ways. The Greek pneuma, Indian prana, Tibetan loong, Chinese qi, Japanese ki, and Native American mana are all believed to be present in the human body and the surrounding environment. Mana, like the energy of the physicists, is thought to underlie, empower, and regulate all physical and mental phenomena.*
>
> *In Buddhism, the energies coursing through the human body are investigated from a first-person perspective by first honing the attention by means of sophisticated contemplative training. Many techniques have been devised to regulate these energies with the practice of physical exercises, controlled breathing, visualization, and mantra recitation. But another approach entails a passive mindfulness*[34] *of the respiration, without trying to regulate or modify it in any way. Through such practice, the energies in the body naturally balance themselves, and in so doing, the mind is also calmed.»*
>
> — B. Allan Wallace, 2004, [160], p. 20

This WLI principle is supportive of the Fourth Principle, and hence it can be regarded as a general law for *energy conservation* mediated through information exchange — *qi/chi/prana* flow and its stagnation with all non-local, but interconnected consequences, as treated e.g. by Traditional Chinese Medicine (TCM) — which demands optimal resource utilization at all levels of organization to ensure and maintain the processes required for system survival (maintenance, repair, replication, etc.) thereby realizing self-reference (introspection, Second Principle, s. Section 3.3) and hence — multidimensional feedback (Third Principle, s. Section 3.4). This is how the *inner loop* of WLI principles 2 to 5 corresponding to the I Ching dialectics [182] is closed.

Availability and utilization of resources can be implemented by expansion of information or probability. WLI is currently using the first option, expansion of information, which is based on analyzing the traffic observation by the netbots and on the analysis of the signals delivered from neighbor netbots. The intelligent decisions to be taken by them have to be a priori defined by some initial rules. However, netbots can also learn from their experience with managing this information flow (e.g. by using deep learning techniques popular in pattern recognition today) and change the parameters of the rules or even autonomously generate new rules for the traffic analysis. Thus the network evolves by optimal use of its resources (s. Fifth Principle) and wandering its functions to the areas they are needed most. If the physical resources happen to be insufficient or exhausted, then the network signalizes where they are needed based on the analysis of its historical records stored in the netbots. As a result new netbots are added or even automatically assembled on demand. Another idea for implementing availability and utilization of resources is the one of Gunji mentioned above with Bayesian and inverse Bayesian inference, [170, 206]. Bayesian inference can correspond to finding an optimal solution for a given environment. In a brain process, that is compared to internal selection of a population of neurons, which can be synchronously fired with the largest domain. An Inverse Bayesian process can correspond to expansion of the context in which an optimal solution is interpreted. In a brain process this is comparable with the usage in various neural domains (global work space).

3.7 The Sixth Principle: Second and Higher-Order Logic

« In my beginning is my end. » ….« In my end is my beginning. »

— T. S. Eliot, Four Quartets, Quartet No. 2: The Coker

«Therefore being and non-being give birth to each other. »

— Lao Tzu, Tao Te Ching, Chapter 2

[34] There are more powerful systems of introspection in Vedic literature such as for instance Ashtanga yoga: review note by Alex Hankey.

The sixth WLI principle adopted from [5] is about second-order[35] and higher-order[36] logic for modeling living systems. The latter are derivatives of Boolean predicate logic[37], an extension of propositional logic[38], which in turn stems from Aristotelian logic[39] (or theory of the syllogism). The Aristotelian bivalent logic laws comprise: i) the Principle of Excluded Third (PET) or *tertium non datur*, 'a third is not given', which states that every claim must be either true or false with no other options; and ii) the Principle of Non-Contradiction (PNC), which states that nothing can be both true and false at the *same* time. This logic draws the demarcation line that divides the thought traditions in East and West[40]. So, why do we need the extension of first-order logic into second and higher-order ones? In first-order predicate logic, variables can appear only inside a predicate, thus allowing the quantification over variables. In second-order logic, one can also quantify over predicates, e.g. $\forall p, \forall x: p(x) \vee \neg p(x) := 1$, which means: for every predicate p, and every variable x, either p(x) or not p(x) is true, regardless of what x is.

One reason for inventing and using higher-order logics is the limited expressive power of lower-order ones when trying to understand complex phenomena of more detail. One way to resolve this is by substituting and relating (mapping) many of these details with functions or predicates in a number of stages (orders, sorts, etc.). Therefore, in set-theoretic terms, a first-order logic quantifies over elements, while a second-order logic quantifies over sets of elements. Hence, a predicate is equivalent to the set of instances that it applies to. In this way we can define higher-order logics by using meta-types, quantifying over sets of predicates (functions, mappings). This kind of logic can be used to define new type systems for predicate logics. They extend the quantifiers of logical expressions from those used for objects only to such used for object properties, object functions and object sets by introducing new sorts (or types) of variables. These variables can range over i) sets of elements, ii) k-ary relations on the elements and ii) all functions taking k-ary elements of the domain as arguments and returning a single element of the domain as result.

The great advantage of second-order and higher-order logic (which better fits in the notions of category theory) over first-order is within their systatic[41] capacity (powerful expressiveness). However, whereas the first-order is semi-decidable (the proofs are verifiable, but not the proposition), with introducing a full second-order logic even the proofs are not verifiable. Hence, there is no clear notion of proof and the metaphysics baggage cannot be eliminated. Therefore, most mathematicians still adhere to first-order logic, which is decidable or provable. How to make second-order and higher-order logic decidable is a big issue in science. In order to specify meaningful statements framed in it, some sort of *qualifier* needs to be used. Information, as a natural phenomenon of a layered, filtered and shared content (syntax, semantics, semiotics) is a crucial factor for making them decidable.

The central point here is that the phenomenology of information is intrinsically decidable if the internalist stance, [93] — that of the first person observer-participant, [103], — is adopted. Thus, second-order logic becomes *analysis*. However, we would like to advance with *a different kind* of *qualifier* and 'second-order'/'higher-order' logic, which goes beyond the classical notions of true and false[42], [132], into the realms of meditative introspection where "the Buddhist epistemologists, insofar as they accord perception a privileged epistemic status, share a common ground with [philosophical] phenomenologists in the tradition of Husserl and Merleau-Ponty…" [149, 1].

35 https://en.m.wikipedia.org/wiki/Second-order_logic

36 https://plato.stanford.edu/entries/logic-higher-order/

37 which supports variables, and quantifiers over variables, e.g. p(x) or $\forall x, \exists y$: $p(x,y)$, [141].

38 A proposition is a predicate without arguments, just symbols such as p **V** q.

39 https://plato.stanford.edu/entries/aristotle-logic/

40 In Category Theory the logic of a topos (Lawvere-Tierney) is intuitionistic and thus may not respect the principles of Aristotelian logic.

41 i.e. when *experienced* as related to a combination or a synthesis of the whole from the parts (systatics) ([207] p. 51ff).

42 In Category Theory this can be modelled by a topos, since "A topos is (the embodiment of) an intuitionistic higher-order theory", ([213], Preface, (iii)).

In Hinduism and Buddhism, the non-committal attitude to the binary logic stemming from the classical Aristotelian dichotomy — either true or false and never both simultaneously — does not rely on the presumption that there is a more accurate semantics reflecting reality, [143-150]. It is rather the by-product of a more fundamental doctrine advocating i) concept renouncement, and ii) abandonment of any conceptual confinement in general. Notions of reasoning such as the principle of catuṣkoṭi (four corners), [144], where claims can be true, false, both, or neither, as well as its later developments adding a fifth possibility, *ineffability* [149], and the Jaina logic [147], offer an invaluable richness for expressing reality states. Zen *koans* which are known for their paradoxical content (from Western viewpoint), serve as literary glimpses into a richer world of experience devoid of some of the most fundamental principles for the Western mind such as Aristotelian bivalent logic and its higher-order derivatives we use in science and technology today. Another narrative example is given by the Japanese *haiku* poetry, which omits some basic grammar constructs we are used to in the West to leave space for a (first-person) perspective of contemplative observation stimulating one's imagination:

Furu ike ya	*The old pond;*	*pond*
kawazu tobukomu	*A frog jumps in –*	*frog*
mizu no oto	*The sound of water.*	*plop!*
Matsuo Bashô (1680s)	R.H. Blyth (Trans.)	James Kirkup (Trans.)

This implicative but rich "reductionism" (s. Section 3.2) allows an easier adoption of 'paradoxical' concepts that modern physics has delivered to us such as the principles of complementarity or wave-particle dualism[43] and quantum entanglement [133], some of which have become cornerstones for the proof of scientific hypotheses. But recently, Western science, which has been based on Aristotelian logic and the deduction method for 2300 years is rising now for a renewal upon such notions as unique distinction [97, 134-136], bijective causality, ([137-139], [145]), bivalent/Boolean logic, [132, 140, 142] and classical self-referent logics [52]. Therefore we regard the sixth WLI principle of an extended notion of second-order and higher-order logic as a noticeable tendency for stepwise enrichment of modal logic towards both Western philosophical phenomenology [1] and Eastern thought.

4. WLIMES as synergetic synthesis of biology-driven mathematics and computation

This section discusses the differences and similarities of the two approaches, which led to their integration as WLIMES. The WLIMES project was proposed by the authors in 2012 [6] to extend WLI by MES, to become amenable for modelling living systems. Co-regulators (CRs) in MES correspond to specialized subsystems of elements, which are not necessarily disjoint, i.e. an element can belong to multiple CRs. Thus, CRs correspond to different (virtual) levels of structural and/or functional organization of the netbots. WLI and MES are complementary formalisms with capabilities at different conceptual levels. Informally we can regard WLI as the physics or the computing implementation of the mathematics in MES. The role of the WLI principles is the same as the one of the physical laws in nature. However, they are defined in a manner to reflect the structural dynamics of living systems with its specific information exchange and multi-level logic. The role of the theorems in MES is to analyse how the transitions between the states of the living system are generated and behave, [14]. Hence, the WLIMES organization is defined by the internal computation processes inside the netbots and by the information exchanged through the shuttles. In this way, WLI determines the operational[44] semantics of the system model WLIMES, whereas MES gives its denotational[45] semantics.

[43] https://www.britannica.com/science/wave-particle-duality

[44] "In an operational semantics we are concerned with *how* to execute programs and not merely with what the results of the execution are." [66, Ch. 2]. „A computational model is a formal model whose primary semantics is operational; that is, the model prescribes a sequence of steps or instructions that can be executed by an abstract machine, which can be implemented on a real computer." [67].

[45] A mathematical model is a formal model whose primary semantics is denotational; that is, the model describes by equations or graphical entities (e.g. nodes and arrows) a relationship between quantities (sets) and how they change over time. The equations (or the graphical entities) do not determine an algorithm for solving them [67].

In fact MES intermingle two mathematical domains, namely Category Theory and (hybrid) Dynamical Systems, which must be rendered coherent.

(i) The structural analysis of a hierarchical evolutive system is purely categorical, as well as the complexification process and its applications to emergence.

(ii) The local dynamic of the co-regulators and their interplay leading to the global dynamic resort to hybrid dynamic systems [188] is a complex theory which has achieved only partial results under strong analytic conditions not always verified in practical applications.

(iii) As already said in Section 2.6, the MES coherence must be ensured at each step, for instance in the complexification process, for finding what are the 'active links' at the basis of the construction of the landscape of a CR, and essentially in the interplay among co-regulators, so that this interplay might not be computable.

Now by uniting MES and WLI, we can somewhat relax the dynamic constraints by "injecting" feedback to MES from the underlying processes through WLI, which initiate local and global changes in the organization and operation of MES. These are also reflected in WLI itself with the change of its organization and operation and the provision of new boundary conditions. Category Theory as such does not consider hierarchies. When mathematicians speak of "higher categories" they mean a hierarchy of concepts: category, 2-category, multiple categories, etc. It is in MES where Ehresmann has introduced the notions of a "hierarchical category", and of a "hierarchical evolutive system" [13]. MES imply both hierarchical structures for the components and their links, and heterarchical ones for their co-regulators (each operating with its own logic and its own temporality with all the CRs being asynchronous, cf. Section 2.6), whereas heterarchical structures among netbots in WLI result from asynchronous temporality (local times) in different areas, as in the case of the CRs of a MES. Thus, collections of co-regulators in MES correspond to those of netbots in WLI, whereas some MES components and their links can be regarded as corresponding to *internal* organizations of individual netbots, which are hierarchical. One of the differences between both formalisms is that in MES there are also components (for instance in the memory, but not only there), which don't belong to CRs; the operations of a CR, such as the formation of its landscape, must also account for these other (non-local) components. WLI achieves this through generating and monitoring the shuttle traffic in the netbots, which can inform and direct CRs which way to go.

Actually, we could speak of *two levels of organization and operation* of these elements, at the MES level and at the WLI level. At the latter, they can occasionally select prioritized execution procedures that temporary take the control and direct the behavior at the former, if certain preset threshold values of the monitored surrounding environment are exceeded. Then the WLI level switches back to the operational semantics mode, as soon as the required changes at the MES level have taken place.

The information about the context (neighborhood) is delivered to the netbots by the shuttles through the established communication channels. To maintain both forms of organization, WLI and MES, the Dualistic Congruence Principle (s. Section 3.2) realizes gradual changes in certain contexts (patterns). This is achieved by letting WLI's machinery provide multiple context-driven feedbacks (s. Section 3.4) to the MES co-regulators allocated in specific netbots (CRs).

> ***Remark 2****: The roles of the active applications (AA) depicted on Fig. 7-8 in Section 3.5 correspond to the functionality of the MES co-regulators associated with a wandering network. There can be 1:1 and n:1 mappings between AAs and CRs. The roles of the executing environments (EE) correspond to the functionality of the netbots realized as operational semantics (OS) in WLIMES. There can be also 1:1 and m:1 mappings between EEs and OSs. AAs and EEs are decoupled and operate asynchronously, with EEs serving dedicated AAs in the netbots. Some EEs can process code delivered by the shuttles to generate new EEs and AAs in the netbot and provide feedback modifying the functionality of the corresponding CR.*

The Wandering Network suggests a dynamic hierarchy within its multiple closures/(sub)networks. The netbots are cooperative; they negotiate their interplay/communication. They could be regarded as CRs in an emerging/development stage. Once the established channels between functional subsystems/co-regulators/netbots become more frequently used, they can build new semi-stable and permanent CRs at different levels. The co-regulators of a MES correspond to netbots or (virtual) clusters of them operating as units and always participating a WLI (sub)network. However the CRs are competitive and can be conflicting.

The netbots execute a double function. On the one hand they realize such operations as addition, loss and binding of functional components inside a WLI closure or (sub)network. On the other hand, they build unidirectional or bidirectional communication channels along which shuttles are transported. This function is realized at different levels of abstraction resulting in the simultaneity of these processes.

A WLI cluster/node/netbot can cease to operate/exist as a result of the interpretation/processing the information contained in incoming shuttles. In this way degeneration, 'aging' and even death of some parts of the wandering network is possible, thus enabling its replacement with new functional structures and links/channels between them. In the same manner operates the regeneration of same former dead areas of the network, once they involve living components, i.e. those at the edges of the network which maintain at least one connection to another netbot and capable to process its shuttles. The realization of such repair mechanisms depends on the particular 'regeneration' policies; the latter are matter of future investigation. In a MES also, both components and CRs may disappear either completely or through replacement by others, and new ones can be created (e.g. by time rescaling and aggregation of patterns, [211]) through the complexification[46] process.

The memory in MES develops in time through learning; it is both robust and flexible; it is centralized, with each CR having its own differential access to it, whereas in WLI it is distributed among the netbots, their components and the exchanged shuttles.

With respect to the (individual) duration of processes, each CR in MES acts stepwise as a hybrid system [188], i.e. with both a discrete and a continuous timescale, the discrete timescale delimiting its successive steps); the change between the situation at the beginning moment *t* and at the end moment *t'* of a step of the CR being caused by the information gathered in the landscape of the CR during the first part of the step (through incoming 'shuttles'), and the results of the procedure selected to respond by the CR. On the other hand, the netbot also causes changes in the shuttle while processing it, thus influencing changes in other netbots receiving that shuttle at a later moment[47]. Thus, the processing and propagation of logical and conventional information is mainly achieved in and through the shuttles, whereas non-logical unconventional processing is mainly performed by the netbots, which serve or occasionally steer the CRs. This can be regarded as another incarnation of the Dualistic Congruence Principle (s. Section 3.2). In WLIMES the commands of the procedure selected by a CR transmit information (through 'shuttles') to other CRs, for instance to effector CRs such as the effectors of a 'muscular' command. Each CR operates as a hybrid system with its own rhythm, so that MES is a multi-temporality system.

The intelligence/plasticity of the system at the moment *t* is the instant result/response of the interplay between its constituting elements (components, netbots and interworking clusters of them). This interplay, mediated by the memory mechanisms and the genome of the living system explains how past, present and future [93-97, 78, 62] intermingle when developing a dialectic between heterogeneous CRs. It is at the root of possible cascades of de/re-synchronizations characterizing the aging of the organism (cf. the theory of aging by such cascades in [14], Chapter 7) and playing a special role in different ailments and their therapies, [100, 101].

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[46] The term "complexification" here is the mathematical construction defined in Section 2.

[47] Again, simultaneity or sequence in time must be defined differently within the new concept of integrative biotime. A 'global' linear time is in view of the phenomenological consequences not the appropriate option.

In MES the interplay is realized through the competition between the commands of the procedures of the different CRs at a given time, and its flexibility comes from the multiplicity principle allowing for processing each command along its most adapted ramification. However, the different temporalities of the CRs in MES and netbots in WLI are registered by external linear clock entities. However, the strictly linear time in the original versions of WLI and MES will be transformed into a multidimensional one in WLIMES with all consequences for the realization of signaling and synchronization in a specific context. There is also a second important aspect of time we wish to address in our research, because of its consequences in systems evolution, diseases and aging. Advanced research in *autoimmune behavior* and collective microbiotic signaling records conflicts between different times/rhythms in the cooperative (and conflicting) modules of organisms. Our approach towards resolving such conflicts is based on the understanding that each such module or co-regulator in terms of MES, [14, 100], operates with its own function, complexity and rhythm, and communicates its state parameters to other modules of the system adopting the mechanisms of WLI [8-9] to implement the global dynamics of synchronicity resulting from the interplay among the local dynamics.

In the WLIMES implementation of the capabilities described in sections 2 and 3, WLI defines an extendible *second and higher-order logic* [5, 53] (or operational semantics for MES [14, 44]), as well as an *environment context feedback* to MES from the lower monitoring and computation layers resulting in CR behavior changes, temporally steered by WLI. This process is going to be enhanced next by virtual and augmented reality (VAR) tools [192], which are intended to support the creative visual modelling of WLIMES systems using an integrated methodology unifying the WLI principles and MES methodology within an interactive design framework. The latter is built on the foundations of Western and Eastern philosophical thought, which are the subject of the previous [1] and current special issues [189]. Therefore, we have established partnerships with research groups working on close approaches such as the Goranson's team on *Two-Sorted Logic* (2SL, [49-50]) with applications in katachi design of self-modifying systems, [190], and the team of Tozzi-Marijuan with applications of topology and gauge theory to cellular organization, [191].

5. Conclusions and Outlook

The WLIMES approach we propose combines the advantages of a multi-scale multi-agents multi-temporality methodology (MES) based on a 'dynamic' category theory and a situation and context aware computational logic for active self-organizing networks (WLI), which are entwined with each other, thus realizing the integral biomathics dialectics at two different levels of abstraction. It is the first step towards modelling and simulation of multi-level living systems. The results of this effort can be integrated within the current methodology and practices of theoretical biology and personalized medicine to deepen and to enhance our understanding of life.

Fig. 9: *I Ching: The Book of Changes*
<u>Circular arrangement</u> (inside-out): Yin-Yang couple, eight (bāguà) trigrams of Taoist cosmology (Earlier Heaven and the Later Heaven sequences) and sixty-four I Ging hexagrams

Characteristic for our approach is its innate relation as practical method, e.g. through *self-introspection*, to both natural and artificial life systems. This paper presents a 20.000 feet view on WLIMES as modern research tool from the perspective of a set of archetypal concepts in ancient Eastern teachings. The 6 WLI principles and the various MES constructions and theorems have been used loosely as system design guidelines so far. Their integration within an "organic" scientific methodology for analysis and prediction of living system behaviors analogous to the one of the ancient (oracle) system of trigrams and hexagrams *I Ching*, (Fig. 9), could suggest ideas for future research. The Book of Changes has been already used in science, [201-202], and we believe to be on the right track.

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