Extended Abstract

Internal Quantum Measurements and the Growth of Information

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Introduction

In the processes of adaptation, development and evolution, living systems interpret themselves in the environment resulting in changes of both. This leads to the growth of information via rescaling of internal time (heterochrony) followed by spatial reconstructions of morphology (heterotopy). The growth of information is based on perpetual changes in its interpretation in the changing world. Biological evolution involves the anticipatory epigenetic changes in interpretation of the genetic information which cannot be generally forecasted but can provide canalization of structural changes defined by the existing organization leading to predictable patterns of form generation. Social evolution is accompanied by unprecedented growth of the informational field that leads to progressive development of human society.

In modern theoretical biology, the internal measurement concept was suggested as a background for explanation of the phenomenon of life (Matsuno, 1995). The quantum measurement represents the action of a measuring device on the measured system. The quantum measurement is an irreversible phenomenon exhibiting itself as a reduction of the potential field. It has also a relation to the irreversibility of time (Igamberdiev, 1993). The collapse of wave function is not equivalent to time until it does not generate a measurable duration, but when its pattern is repeated consistently, the clock can be set, and the system becomes organized in time. When the measuring device is a part of measured system, the measurement proceeds internally in relation to the whole system and the latter becomes more complex as a result of measurement itself. The aim of this study is to discuss the role of internal measurement in the growth of information in evolving systems. This can refer to biological evolution, social evolution, and as well to the cosmic evolution, which is represented in the phenomenon of expansion of the Universe.

Internal Measurement and the Generation of New Information

The internal measurement leads to an iterative recursive process which appears as the development and evolution of the combined system containing the measuring device and the measured object. The quantum measuring device can be organized in such way that it "encodes" the system in the course of interaction with the measured object, and makes it possible for the measurement to proceed in a regular way. In this case, such system can memorize the evolutionary complication of organization in a digital information-bearing subsystem and evolve further; in other words it contains an internal description memorizing the result of measurement. The logical precondition of the growth of information in this evolving process is the incompleteness of biosystem's internal description, while the physical precondition is the uncertainty of quantum measurement. The evolutionary increase of complexity becomes possible when genotype appears as a system distinct from phenotype and is embedded into it, which separates energy-degenerate rate-independent genetic symbols from the rate-dependent dynamics of construction that they control (Pattee, 2001). Evolutionary growth of information becomes its own cause, a universal property of our world.

The growth of information accompanies the appearance of measurable time that occurs in the systems performing quantum measurements in a regular way, with low dissipation of energy (Igamberdiev, 1993, 2004). These systems are modelled as hypercycles and can be defined as structures in which the subset of a substrate set of the catalytic system happens to be the matrix for generating and reproducing the set of catalysts itself (Igamberdiev, 1999). This definition keeps the main features of the original notion of hypercycle given by Eigen and Schuster (1979). The hypercyclic system is closed in the way that all of the catalysts needed for an organism to stay alive (representing an efficient causation according to Aristotle and forming organism's spatiotemporal structure) must be produced by the organism itself, only relying on matter and energy from the outside (Letelier et al., 2011). When hypercycles appear in evolution, time becomes an independent measurable variable due to the internal reproducible changes. Hypercycle organizes irreversibility of quantum measurement into a measurable duration.

Eigen's hypercycle is a formalized representation of the autopoietic system of Maturana and Varela or Rosen's (M,R) system (Leteiler et al., 2011). The system becomes an internal autonomous clock that distinguishes the past (memory), the present (life), and the future (anticipation based on the reproducible model), so the modeling, logic and digital information growth become possible within the system (Rosen, 1985). The hypercycle having own embedded description, becomes a structure that realizes computation in accordance with its internal logic defined by the embedded description. The latter has the property of incompleteness which is reflected in the fact that quantum correlations of the states of the system are associated with undecidable logic theories, i.e., they can potentially generate the statements not defined within the system. The undecidability can be interpreted in the sense similar to the Gödel's incompleteness theorem, meaning that there exist propositions, expressible in the formal logic, which cannot be proven or disproven (Briegel et al., 2009). These propositions become the grounds of expansion of the system and its informational growth.

From the quantum mechanical point of view, the emergence of a new statement results in acquiring a new error-correction meaning to support the internal quantum state (IQS) (Igamberdiev, 2004, 2007). The IQS keeps the system organizationally invariant. It is supported by the set of error-correcting commands that aim to keep IQS free from external demolitions. The error-correction information becomes an important part of the whole informational field. A new statement makes the system more

complex (it leads to an increase of its informational content), with its all spatiotemporal organizational invariance be rescaled. In the course of evolution, an available element of a formal system (similarly to a word when used as a metaphor) can acquire another (in addition to already existing) value that contributes to formation of a new level of organization in the system. The logical basis of this action is the incompleteness of the existing formal system that allows assigning arbitrary values to the statements non-provable within that system, while the physical basis is the quantum uncertainty arising in quantum measurement. A new statement can arise from existing elements by acquiring the double function, however, for fixation of this new statement via expansion of existing formal system, some informational redundancy of the system is needed, which can be achieved by multiplication of some of its elements.

Genome is a system which possesses an internal complementarity between the linear texts and their superposition. Relevantly to this, complementarity means that text and hypertext cannot be viewed at the same moment: they should be separated by a time interval. It is an example of uncertainty between the system and its embedding. Overlapping genes, alternatively splicing sequences, RNA and DNA editing, introns, and recombination according to molecular addresses are the features of this hypertext generating a potentially infinite number of language games. Genome as a complete language exists as a complementary set of its alternative combinations resulting in logical paradoxes which determine its temporal dynamics (Isalan, 2009). This superposition is a basis for ontogenesis, adaptation and evolution. Thus, the total "true" genome is a superposition of contradictory arrangements, which generate one single arrangement at a concrete moment of time. The pool of mobile genetic elements expands the combinatorial capacity of the genome by many times. An ambiguity in meaning is analogous to the quantum uncertainty principle in which it is impossible to define strictly the position and impulse of a particle simultaneously, or to fix certain energy in a very short period of time necessary for its registration.

The question of a minimal size of the autocatalytic self-reproducing system and its composition has been discussed in several works (Sharov, 2009; Steel et al., 2013). Self-reproduction itself is a creative process of placing text in text with following self-growing of this joint structure. Any evolutionary change also begins from the placing of "text into text". This is possible because genome is structurally adapted for realization of such a non-trivial function. Moreover, even a point mutation or deletion may be considered as generative if it is placed in the repeated (e.g., diploid) structure. The doubling is a premise of metasystem transition, which includes duplication of the original system and the establishment of control over multiple copies (Turchin, 1977). The evolutionary significance of gene duplication was considered by Ohno (1970) as a premise of neofunctionalization. The advantage of sexual reproduction is in the casual combinatorial generating of new statements from two separate texts that can acquire meanings, thus it resists evolutionary degradation. It becomes a prerequisite for growing of information and complexity (Igamberdiev, 2014). The combinatorial interaction of heterochronic texts generates a new system in which the internal time is rescaled in a new way that generally cannot be forecasted. The heterochronic duplication (via hybridization of temporally different organisms) generates more possibilities for the metasystem transition. Thus, the incompleteness of embedded set of symbols is the formal cause of evolution. The physical representation of this incompleteness is a quantum uncertainty in the course of measurement (Matsuno, 1992). It spans from the level of elementary particles to biological evolution and to the phenomenon of free will and consciousness.

Growth of Information in the Expanding Universe

The growth of information that we discuss here mainly in relation to biological evolution is relevant also to the physical space-time scales. The self-growing principle of quantum measurement has a property of intrinsic expansion of the informational field. The relationship between observable nature and a hidden "potential" nature is modeled, according to Kineman (2010), as an imaginary space-time domain geometrically represented as radial "Minkowski-space". Despite of the fact that local space and time are normally represented as real numbers, the general relationship in this geometry is hyperbolic in accordance with the special theory of relativity. When mapped as a radial geometry, the space-time is seen to be intrinsically dynamic (expanding) and self-similar across all scales. The geometry has the properties of early and present acceleration. This representation eliminates the "light cone" and thus all regions in this model are the domains of existence and are observable over time. Nevertheless a domain of general, non-local reality is represented in the imaginary axes that exist simultaneously with measurable, local domains.

The Universe in the concept of Kineman (2010) consists of the units called "holons", which vaguely correspond to Leibniz's monads. They possess simultaneous properties of location and non-location, as a point of non-differentiated whole appearing in a subject-object relation. The Everett's interpretation of quantum mechanics works in these isolated domains but not between the domains, the same idea has been suggested by Matsuno (2012) for the individual biological systems taken as separate domains. The reality of superposition of the wave function is limited by the single monad and does not expand outside it, and in this sense monads do not have windows as originally proposed by Leibniz.

Conclusion

The growth of information is the basic property of evolving systems and it follows from the interaction between non-local and local domains in the course of internal quantum measurements. The internal measurement leads to an iterative recursive process which appears as evolution of the combined system containing the measuring device and the measured object. The system through measurement acquires the property of expansion, which is seen in biological evolution, social development, and at cosmic scales as expansion of the Universe.

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