Dualism of Selective and Structural Manifestations of Information in Modelling of Information Dynamics

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Abstract. Information can be defined in terms of the categorical opposition of one and many, leading to two manifestations of information, selective and structural. These manifestations of information are dual in the sense that one always is associated with the other. The dualism can be used to model and explain dynamics of information processes. Application of the analysis involving selective-structural duality is made in the contexts of two domains, of computation and foundations of living systems. Similarity of these two types of information processing allowing common way of their modelling becomes more evident in the naturalistic perspective on computing based on the observation that every computation is inherently analogue, and the distinction between analogue and digital information is only a matter of its meaning. In conclusion, it is proposed that the similar dynamics of information processes allows considering computational systems of increased hierarchical complexity resembling living systems.

Keywords: Selective and structural information, Dynamics of information processing, Hierarchic levels of information.

1 Introduction

The concept of information has several very different definitions. In this large variety, only few qualify as correct and intelligible. Too frequently, definitions simply refer to intuitive understanding of the explanatory concepts selected from the vernacular vocabulary. It is quite rare that the formulation of the definition refers to any particular philosophical background. However, there are two clearly distinctive or even competitive tendencies in the understanding of information. One is characterized by explicit or implicit reference to selection, sometimes in alternative form of difference or distinction. The other has the general idea of the form or structure as the focal point of explanation.

The definition of information used in this paper was introduced and extensively analyzed in earlier articles of the author. Its desirable feature is that the both ideas of selection and of structure can be found as alternative and complementary ways of its interpretation.

Moreover, it turns out that the selective and structural manifestations of information are dual in the sense that one always is associated with the other. The dualism is

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being used in present article to model and explain dynamics of information processes. Dynamical processes of this type are analyzed in contexts of the two domains, of computation and foundations of living systems, but there is nothing which would limit this model to any particular domain. In conclusion, it is suggested that the similar dynamics of information processes allows considering computational systems of increased complexity resembling living systems.

Due to the scope and limitation of the format of this paper more detailed presentation of the technical issues related to mathematical theory of information developed by the author for the description of the dual concept of information and of information dynamics will be published elsewhere.

2 Dualism of Selective and Structural Information

The concept of information is understood here in the way it was defined in earlier papers of the author [1] as an identification of a variety. Thus, starting point in the conceptualization of information is in the categorical opposition of one and many.

The variety in this definition, corresponding to the “many” side of the opposition is a carrier of information. Its identification is understood as anything which makes it one, i.e. which moves it into or towards the other side of the opposition. The preferred word “identification” (not the simpler, but possibly misleading word “unity”) indicates that information gives an identity to a variety, which does not necessarily mean unification, uniformization or homogeneization. However, this identity is considered an expression of unity or “oneness”.

There are two basic forms of identification. One consists in the selection of one out of many in the variety (possibly with limited degree of determination which element of the variety is selected), the other in a structure binding many into one (with different degrees of such binding). This brings two manifestations of information, the selective and the structural. The two possibilities are not dividing information into two types, as the occurrence of one is always accompanied by the other, but not on the same variety, i.e. not on the same information carrier. For instance, information used in opening a lock with the corresponding key can be viewed in two alternative ways. We can think about it as a way to make the selection of the key, out of some variety of keys, or we can think about the spatial structure of the key which fits the structure of the lock. In the first case, the variety consists of a collection of keys, in the second the variety consists of the material units (for instance molecules) forming appropriate geometric shape of the key. It can be easily observed that the varieties in this example are related hierarchically. Every element of one variety (keys) is an instance of the other (molecules to be bound into a key). Thus, we can consider selective and structural information as dual manifestations of one concept, with the duality related to objective, structural characteristics of reality.

Coexistence of different manifestations of information justifies introduction of the concept of an information system understood as a complex of varieties (information carriers) whose forms of identification are pair-wise combined through selective-structural duality. Going beyond a pair of information carriers will be considered later in the context of systems in which a hierarchic chain of related pairs can be identified, as for instance in living systems.

As mentioned above, the identification of a variety may differ in the degree. For the selective manifestation this degree can be quantitatively described using appropriate probability distribution and measured using for instance Shannon's entropy, or more appropriate measure when we want to characterize information within the system, not its transmission between systems [2]. For the structural manifestation the degree can be characterized in terms of decomposability of the structure [3].

Selective-structural duality of information is reflected in a variety of contexts. An example of very general character can be found in the way how we form concepts. One way is focusing on the denotation and the selection of objects which we want to include in denotation. Another way is to focus on the connotation determined by the configuration of characteristics which describe it.

Another example can be found in the analysis of scientific or philosophical inquiry. In his philosophical analysis of the methods of science and history Wilhelm Windelband [4] introduced frequently revoked distinction, or even opposition of nomothetic and idiographic methodologies. The former has its starting point in the acknowledgement of the differences, but assumes the existence of similarities which produce grouping within the variety, and therefore it is looking for comparable aspects and serves identification of the subject of study. The latter is assuming the uniqueness of the object of study and therefore is focused on elements which constitute this uniqueness through specific structural characteristics. Although, the distinction is between methodologies of inquiry, not between manifestations of information, association with information is quite evident.

Similar, but much more frequently used distinction in the context of cultural studies has been introduced more than a half century later by Keneth L. Pike [5]. He called his methodological schemata etic and emic methodologies, deriving their names from phonetic and phonemic studies of language. Here too, the distinction is based on the differences in the perspective of the study. In the first case the subject of study is viewed in a comparative manner as a member of a variety in which differences and similarities are used to establish its unique characteristics. In the second case, the subject of the study, whose uniqueness is already assumed, is viewed from the inside with the aim to reconstruct its internal structure.

In these examples, as well as in all instances of the reflection of the selective-structural duality in methodological analysis, it is considered obvious that the choice of a particular method is dictated by the discipline of inquiry. Physics for instance is recognized always as a paradigm of the nomothetic or ethic approach corresponding to selective information. After all, probability distributions describe the state of a system, collective one in classical physics, and individual in quantum physics. But closer look reveals that actually in this domain both methodological positions are omnipresent. It is enough to recall tendency of geometrization in physics continuing beyond the General Relativity Theory, or the special role of the field theory to recognize the presence of the view associated with structural information.

The selective-structural dualism of information can be found not only in the distinction of methodological perspectives in physics. Wave-particle dualism which is understood as a characteristic of physical reality at quantum mechanical level can be interpreted as an expression of the dualism of selective and structural manifestations of information. Corpuscular image of an electron is based on the selection of its position out of a variety of possibilities described by a probability distribution. Wave image is based on the structural characteristics of the space.

The most significant is association of the selective-structural dualism of information with the dualism of function and structure in the foundation studies of living systems, which constitutes the central theme of the work of Humberto Maturana and Francisco Varela [6] on autopoiesis. Here it becomes clear that this dualism is not just a matter of the choice of a method of inquiry, but it is a characteristic of living systems. Function determines structure and structure determines function. Maturana and Varela were looking for the resolution of this convolution in autopoiesis, self-construction of living systems. However, from the point of view of information studies, there is no need to restrict this dualism to living systems, as it is simply reflection of the universal dualism of selective and structural information. Functions of the elements of a system give them identity by distinguishing them from, and giving them their place in the differentiated variety. On the other hand, this distinction is a consequence of the specific structural characteristics that they posses, their internal structure allows them to play specific roles in the system. It is not a matter of the right or wrong perspective of the study, but an inherent feature of all information systems.

Mathematics provides several different examples of dualism which can be very clearly associated with that of selective and structural information. The most fundamental can be traced back to the 19th Century when Felix Klein formulated in his 1872 Erlangen Program the view of geometry as a theory of invariants for the group of transformations of a geometric space. Instead of identification of the objects of geometric studies through analysis of their internal structure, the structure of transformations of the plane or space is selected, and only then geometric objects appear as those subsets of points which are transformed into themselves, although their points may be exchanged. Such an approach, in which instead of inquiry of internal structure of objects, the structure of transformations preserving the identity of these objects (i.e. selection of invariants) is analyzed, has become commonly used in a wide range of mathematical theories leading to the development of the theory of categories and functors.

In the past, the dualism of selective and structural information has been present in information studies only in the form of a competition between two, apparently conflicting views on the "proper" answer to the question "What is information?" [1]. The dominating position focusing on the selective manifestation of information and neglecting the structural one was supported by the practical success of Shannon's quantitative characterization of information in terms of entropy. But the failure in establishing equally successful semantics for information understood exclusively in terms of selection was driving the efforts to shift studies of information to its structural manifestation.

The dual approach achieved through the definition of information used in the present paper has more advantages than just reconciliation between adherents of competing views on information. It also helps to model dynamics of information in processes of evolution or computation.

3 Dynamics of Information in Computing

The definition of information in terms of one-many opposition has been a starting point for author's attempt to formulate a theoretical framework for information [7]. This framework has a static form reminding logical structure, at least in the sense of similarity of the mathematical formalisms. However, the formalism used by the author can be used to model process of information integration which can be interpreted in terms of temporal orientation (input/output) [3].

The change of the level of information integration is not a dynamical process, understood as transformation resulting from the interaction of different information systems. For this reason, information integration, although modelled by a theoretical device called a Venn gate in the earlier papers of the author should not be confused with traditionally understood computation.

What is computation in the present conceptual framework? First, we have to clarify some quite common confusion related to the distinction between analogue and digital computing. The distinction between "analogy and digital" principles, automata, or machines introduced by John von Neumann [8] at the time when first computers were being constructed was referring to the way the numbers are represented, by certain physical quantity, or by "aggregates of digits."

For von Neumann the main issue here was in handling errors. He wrote "Thus the real importance of the digital procedure lies in its ability to reduce the computational noise level to an extent which is completely unobtainable by any other (analogy) procedure."

Of course, von Neumann was right about practical advantages of "digital procedure" in handling errors, but he overlooked what actually constitutes the distinction and why it is important outside of practical considerations of precision. The mistake he made is being perpetuated even now. Of course, the numbers are always represented by physical quantities, even in digital computers. For instance, the typical implementation of computing units associates digit 1 with one physical state and 0 with another physical state. But it is only an interpretation of the distinction between two physical states. Moreover, the positional numerical system used in this interpretation is not based on aggregation of digits, but on very specific and conventional structural rules. "Aggregates of digits" do not exist independently from the physical systems constituting machines or any other computing systems. To that extent everyone will agree with Ralph Landauer [9] that information is physical.

Thus, the actual distinction is in the semantics of information. It is the way how we associate numbers with physical states of the computing machine which decides whether computing is digital or analogue. Information itself is neither one, nor the other. Cat is not becoming more English, when described with the English word "cat".

To avoid going too far beyond the scope of this paper, simplifying assumption will be made that information is associated with the state of the physical system which is used as a computing machine. Then, observables will assign numbers to particular states, giving meaning to information, but we have to remember the lesson from quantum mechanics making clear distinction between the concepts of a state and an observable [10]. As a consequence, every process of computing is a physical process with some dynamic characteristics. Association of numbers with the states of the computing system belongs to the interpretation of information, the same way as in physics observables provide numerical interpretation of the states of a physical systems. Numerical values of observables cannot be identified with states, and therefore cannot be identified with information involved in the process of computing. The same applies to the choice of the numerical system used to represent numbers.

Recognition of the fact that every computation is being carried by some physical information systems justifies the interest in its description as a dynamical process. However, the dynamics of computation does not have to be understood in traditional terms of mechanics. Physicality of computation is just a matter of the ontological status of information systems involved.

We can find some analogy with the status of the Second Law of Thermodynamics, in its interpretation introduced by Boltzmann. We can apply this principle to every sufficiently complex system without any reference to standard physical observables. However, its validity requires that this complex system has the ontological status of a part of the physical reality with all its consequences.

Now, when a justification of our naturalistic perspective is presented we can begin analysis of the process of computing modelled by Turing machines. Once again we have to be careful with traditional way of imagining of the process. Traditional vision of computing is similar to the way people were interpreting mechanical processes before Isaac Newton introduced his Third Principle of Mechanics. In pre-Newtonian vision of the world, every change had to have an active agent (subject) and passive object of the action. Newton recognized that in mechanical phenomena there is no action, but only interaction. The Third Principle states that we cannot distinguish between an agent and recipient of action, as we have always mutual interaction. I cannot claim that my pushing the wall is in any way different from wall's pushing me, as long as we analyze it in terms of mechanics.

From this point of view the interpretation of a head in Turing machine printing a character on the tape is an arbitrary assumption. If we want to consider process of computing in a naturalistic perspective, we can simply talk about mutual interaction in which characters change (or not) on the tape in contact with the head, and the head is changing its state/instruction in contact with the tape. In literally understood physical model of Turing machine, the change of the head may be negligible. But in general we cannot exclude this change from consideration.

More precisely, we could describe Turing machine as a device consisting of two information systems, which in order to retain traditional terminology are called a "tape" and a "head", each consisting of independent components being themselves information (sub)systems. For the tape, components are cells. For the head, subsystems are positions of instructions on the list. At every moment both systems have finite, but unlimited number of engaged components (non-empty cells, or non-empty instructions), and the number of engaged components can grow without restriction.

Each component (cell or position on the list of instructions) is capable to assume one of the finite number of states (possibly different for the components of the tape and the components of the head). For cells on the tape the states are characters in the traditional description of Turing machine. For components of the head (positions on the list of instructions), there is a finite number of choices for an instruction which give the position particular state. Also, we can assume that in the initial step of computation only finite number of positions have nonempty instructions.

Now, we have a crucial and restrictive assumption that these two fundamental information systems can interact only by the contact or interaction of a single pair of active components (which corresponds to the traditional assumption that the head is in the state with one particular instruction, and it can read and act on a single cell).

Experience from the studies of Turing machines suggests that the assumption is not restrictive as long as the difference between one pair of active components is contrasted with clearly defined finite number of pairs. The restrictive character appears when we exclude the possibility of interaction on the scale of all systems.

The process of computing is described as follows. The active cell is changing (or not) its state (character) into one determined by the state of the active component of the head (particular instruction in the position on the list for given state). On the side of the head the change of the instruction depends on the state of the cell (character in the cell). Then both fundamental information systems change their active component. Again this change on the tape depends on the state of active component of the head, the change in the head depends on the state of active cell (character).

Thus, the dynamics of computation considered as an interaction of two information systems consists in the change of current states of both active components, that of the tape and that of the head. The change is a mutually conditioned selection. Also change of the choice of active pair of components is similarly cross related. The crucial point is that the interaction acts as a new information system which cannot be reduced to interacting systems. The variety involved consists of all possible pairs of states which can be selected as an outcome of the step in computation. Another, independent information system consists of all possible selections of the pair of next active pair.

In traditional description of a Turing machine the information regarding dynamics of the process (how components are changing and what the choice of next pair of active components is) is "physically" located in the head or on the tape. For each step of computing, it is located within the instruction as a conditional statement of doing something, if the current tape cell has given state. However, there is nothing that compels us to such model. Equally well we can think that the instruction has form of a character, and what is happening with the tape is a result of the reaction of the tape's active cell to this character, and of selection of the next pair of active components activated externally but conditioned by the states of the pair of present active components.

This machine is little bit more general than Turing's A-machine, as the process allows changes of instructions in the head. This machine could be called a symmetric machine (an S-machine) because the process consists in mutual interaction producing similar type of change. It is being reduced to usual Turing A-machine, if we additionally assume that the instructions in the head are not changing. Of course, this assumption is making Turing A-machine a special case of an S-machine.

There are several natural questions regarding this generalization. For instance, whether for every S-machine there exists an equivalent A-machine producing the same outcome on the tape after computation performed on arbitrary input tape. Another example would be the question about universal S-machines (machine which can produce arbitrary global finite state of the tape, by appropriate choice of the initial global state of the tape, but without any change of the state of the head. However, for general S-machines we have also dual questions regarding configuration of instructions after computation or the minimal number of instructions which produce the same outcome of computation.

At this point we can observe that as long as we are interested in the relationship between computation and fundamental characteristics of life (or living objects), in contrast to traditional studies of computing, it is non-computability which is of special interest. If living objects perform some process of computation, achieving the final stage of computation is a death of the system. Thus, sustainability of life is more likely to be associated with non-computability. However, this issue is outside of the scope of the present paper, since we are more interested in similarities between the two domains, than differences.

For the symmetric Turing machines describing a general dynamic process of the interaction of a pair of complex systems with a restricting assumption that the interaction is in each moment through exactly one pair of active components (mild restriction), we can consider additional distinction between deterministic and nondeterministic machines. The distinction is based on the requirement that the choice of the next pair of active components is strictly determined by the states of the present active components, not random or determined only up to some probability distribution (rather strong restriction).

Even with these two restrictions, symmetric Turing machine gives us a model of information dynamics applicable to a very wide range of information systems.

We know that computation cannot be reduced to one information system. Claude Shannon [11] showed that the head of Turing machine has to have at least two different states. Similar requirement of at least two characters for the tape is obvious. Once we have a variety of two states and choice between them, we have an information system.

Now, the dynamics of the process of computation is revealed in the selective-structural dualism of information. For both fundamental information systems (tape and head considered globally) information is structural. The state of all tape consists of configuration of characters in its cells, but computation is an interaction in which the choice of one out of many states (characters) for the active component (cell) is being made. Similarly, the state of the head is in the configuration of instructions, but in each step of computation one out of many possible choices of instruction is being made. The selection of states and active components is shaping the global structures of the tape and of the head. However, process of local selection is dependent on the global structural characteristics of the tape and the head.

Finally, we could consider an extension of the process of computation using the concept of selective-structural information dualism. While computation considered at the level of active, interacting pair of components refers to the selective manifestation of information (e.g. selection of a character for the cell), each character can be understood as structural manifestation of information, if we can decompose it into a variety of elements with some structure. Corresponding to this structural manifestation, its selective counterpart can be subject to interaction which results in its own dynamics. This way we can consider multi-level symmetric Turing machines, which resemble systems encountered in the study of the foundations of life.

4 Dynamics of Evolution

Before we enter the analysis of evolutionary mechanisms, it is necessary to consider more general issue of control systems. In this domain the most fundamental principle has been formulated by W. Ross Ashby as the Law of Requisite Variety "A model system or controller can only model or control something to the extent that it has sufficient internal variety to represent it" [12], [13]. This principle in the informal, intuitive form and in application to the process of generation, not to the modelling or controlling has been until the end of the 18th Century used as an argument for the hierarchy of beings and the need for supremely intelligent creator acting intentionally to generate them [14].

It seemed obvious that any complex system can be generated only by a system of higher level of organization. This reasoning is based on the assumptions that creation is an action (not interaction) and requires a design. Following the Law of Requisite Variety such a design, i.e. internal model is impossible without higher degree of variety. Evolutionary model of the development of life disposed of the design putting this higher level of variety in the environment. Thus the species are getting increasingly complex by the interaction with the environment, which of course is a carrier of a huge amount of information.

Let's start from a dualistic model of relatively simple mechanism of feedback control. It requires interaction of two information systems. Selection of a state of one of them through interaction is accompanied by the selection of a state of the other, which in turn has its reflection in the structural manifestation of information. This structural manifestation of information in the second system is determining the structural information of the first system. And this corresponds to the modification of the selection of its state.

For instance, using classical example of a governor controlling work of the steam machine, we have two information systems which can be in a variety of states. One is a valve whose state (described by the amount of steam passing through it) decides about the speed of the work of the machine. The other is a pair of balls hanging on the arms rotating around the vertical axis whose rotation is propelled by the machine. Its state (velocity of rotation) is selected by the work done by machine. From the structural point of view, information is manifested by the geometric structures of the systems, diameter of the valve and extension of the arms on which the balls are attached. The higher is extension of arms, the smaller diameter of the valve.

Interaction between the two information systems is as follows. Choice or selection of the amount of steam is determining the choice of the velocity of rotation. But velocity of rotation corresponds to the structural information regarding position of the balls. Position of the balls (structural information) is determining the structural characteristics of the valve. And finally this structural information corresponds to the selective manifestation in form of the amount of steam flowing through the valve.

The governor is a simple case of an artefact invented by humans, originally with the intention to control the speed of work of windmills. There is more complicated situation when we want to explain the dynamics of information in systems which were naturally generated without any intentional design.

We can proceed to the dualistic description of the evolutionary process. Here, in distinction from the earlier example where the function was a result of human invention and the structure followed the needs of implementation, we can encounter confusion which puzzled generations of biologists, but which can be easily resolved within the dualistic perspective.

The mechanism of evolution is usually reduced to natural selection in which the fittest organisms survive and reproduce transmitting and perpetuating their genetic information. The puzzling question is about the meaning of the term “fittest”. Does it have any other meaning beyond the tautological statement that these are organisms which survived and reproduced?

The answer is that the meaning of the term “fittest” is expressing the relationship between two manifestations of information. While naturally, natural selection describes the dynamics of information for selective manifestation in terms of reproduction (which obviously requires survival), the fittest individuals are those whose phenotype has structural characteristics compatible with structural characteristics of the environment.

More generally, we can describe the evolutionary process as such in which two (or more) information systems interact. Interaction is determining the outcome of the selection, and therefore the dynamical view seems more natural in terms of the selective manifestation. However, it is the structural manifestation of information which actually demonstrates the results of evolution. And what is most important, there is no point in asking which manifestation is more important, primary, or true. Dynamics of information has two manifestations, simply because information does.

5 Dynamics of Information in Living Systems

Thus far we were talking about biological evolution of species as a dynamical information process. We were concerned with the question how this process can be understood. There is another, much more difficult question why it occurs, and why in this particular way. To seek the answer, we have to consider more general issue of the dynamics of information in the living systems. Naturally, it is equivalent to the inquiry regarding the question “What is life?” We will consider here only some aspects of this extremely broad and deep problem. Specifically those related to the selective-structural dualism of information. The issues related to the necessity of holistic methodology in the study of life are presented in another article of the author [15].

The main fallacy in answers to the question “What is life?” is in the attempt to explain life by distinguishing one particular process driving and determining all other in the multi-level hierarchical structure of the biosphere. This fallacy is being perpetuated even in most recent publications [16]. The process chosen by the authors of explanations could be photosynthesis (but, what about forms of life which do not depend on it?), metabolism, reproduction with transmission of genetic information, formation of large organic molecules, etc. In each case, authors believe that life can be reduced to one particular level of organization, in analogy to mechanical systems built from basic subcomponents or to the vision of the world built from fundamental particles (“atoms”) through their aggregation.

Another problem is in the restriction of attention to what is called a biosphere. In the earliest fundamental answer to the question Erwin Schrödinger [17] pointed at what he called negative entropy of the light coming from sun as the factor driving processes of life. It is also a fallacy perpetuated continuously by generations of authors who change the name of the factor (negentropy, entropy deficit, inhomogeneity, etc.) but do not notice that the light coming to earth does not have high or low entropy. It is a matter of the process in which incoming visible light, for which the atmosphere is transparent, is transformed by living systems and reradiated into cosmic space as infrared radiation of 22 times higher entropy [18]. Thus, it is not that light coming to Earth has low entropy, but that we have complex process which is making this entropy low relative to the outcoming radiation. There is nothing which prevents this infrared radiation to drive processes of life somewhere else, if re-radiated from there longer-wave outcoming radiation could have entropy several times higher than radiation coming from Earth.

Thus, the driving factor is a mechanism which transcends biosphere and which has its source in astronomical phenomena of huge spatial and temporal measures. But this driving factor itself would not produce life processes. It is just a necessary condition for life. It creates conditions allowing generation of information participating in the dynamic processes of life at all of its levels. Life cannot be understood by observing only one of these levels, as it is usually done. We can artificially generate processes from one level in a system of limited complexity, but they cannot continue functioning independently, and this lack of ability to survive excludes considering such a system as living.

Of course, evolution of species, cycles of metabolism, photosynthesis, or reproduction are component processes of life. But neither has privileged or exclusive position. We can ask however about the common features for component processes of life. Here we can find again help in the dualistic perspective on information, and the concept of information definitely is the best candidate to unify description of all life processes.

The main characteristic of life processes consists in enriching information in one system of a smaller variety, i.e. lower informational volume through the dynamic interaction with another of a large volume. This process was already described in a general view of the dynamics of information in the evolution of species. We need in this case generation of a large variety of objects and interaction with the other system which selects some of them (the fittest) whose structural characteristics predestine them to survive. Thus, the collective system is increasing its organization (internal information) not because they have some design, but they fit selective information of the outer system. The crucial point is in inseparable dualism between the two manifestations of information and multi-level character of the total system. The multiple levels can be identified at intra-organismal and at inter-organismal side of the organization of life. Typical approach in determination of the levels is the use of either functional (selective) aspect of bio-dynamics described above in the context of the work of Maturana and Varela, or structural characteristics. However, we should be aware of their dual relationship.

6 Conclusions and Future Work

There are two domains of special interest where dualism of selective and structural information can be used to model dynamics of information, computation and living systems. Although in both cases dynamics is similar, there is a big contrast between the levels of complexity between them. In what here was described as a slightly more general view of Turing machines there are two information systems (tape and head) which are considered at the two levels corresponding to selective and structural information.

Life constitutes an extremely complex system of at least dozens of levels and the number of component information systems exceeding any practical limits of calculation. However, the basic mechanism involving in its description the two manifestations of information is the same as in symmetric Turing machines.

On the other hand, there is nothing which prevents us from designing computational systems of complexity going beyond two levels. This may require more complicated (multilevel) semantics of information (which in traditional Turing machines is typically an association of particular combination of the states of cells with natural numbers). Each cell may be considered a carrier of an information system with its own variety and with dynamical mechanisms of evolution adjusted to the conditioning by higher or lower levels of the hierarchical structure.

The study of such theoretical systems and their practical implementation is of some interest and has a potential wide range of applications.

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