Information and levels of representation

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Abstract

It has been claimed that representational models of cognition are not adequate for explaining the behavior of complex informational processing systems. The reason given is that these systems are not necessarily symbolic and do not obey computational rules. Can there exist systems that, although representational are not of the symbolic kind? Semiotics has proposed interesting concepts for these models.

Keywords*: representation, information processing, complex systems, semiotics.*

1-Introduction

Complex information processing systems (IPS) are systems that process a special type of object called information. They transform their input into some sort of code, process it in a complex fashion and produce some expected output. But, when the time comes to give a formal definition of what is an IPS, things are not so clear. Here are a few typical samples of these definitions:

> *"[An information system] is a real world system, or a bounded portion of that system. That is the subject of an information system. " (Flavin, 1981: 24).*

> *" An information processing system […] is a computer based system that represents, maintains and provides access to large amount of information about a domain. Intelligent information systems are information systems which include components built through AI technology. " (Mylopoulos et al., 1993: 206)*

As one can see, such definitions are very general if not redundant. And to give a sharper one, we must understand the concepts on which they are based, such as *system*, *process*, and most of all *information*. This last concept is the key one: it is the object on which a process is said to be applied. But what is information? What kind of object is this?[1] Recently, some answers have been given to these questions.

A first one, coming from the classical trend of cognitive sciences has asserted repeatedly that the real nature of information is " representational ". The main hypothesis of this position is that processing information for a cognitive system is to manipulate something that «stands» for something else that is to say, represents something else.

[1] We all know about the Shannon type definition of information. But this is not a definition but a measure of the probability of information. It leaves the concept, as Drestke (1982) said, quite undetermined.

We are dealing with information-processing machines, and the way such machines work is by using symbols to stands for things to represent things, in our terminology. " Marr, 1980: p. 21

This hypothesis can be found in cybernetics (Turing, 1937; Ashby, 1956; Von Neumann, 1958; Pylyshyn 1984) in artificial intelligence (Newell and Simon,1976) in analytical philosophical of mind (Fodor, 1975; Dennett, 1978; Haugeland, 1986). It is also to be found in more recent emergent models of IPS such as connectionists, (Rumelhart and Mc Lelland, 1987; Smolensky, 1988; etc.), genetic algorithms (Holland, 1975) etc..

Many critics have been formulated against this hypothesis. The most classic ones are inspired by Wittgenstein (Cummins, 1989) for whom the concept of representation does not have much explanatory power. Others, (Dennett, 1978; Clark 1989; Putnam,1988) call upon the infinite regression argument, that is, representations require an interpreter or a homunculus that understands this representation but who himself uses a representation to do so and hence need, in turn, another interpreter, and so ad infinitum. Connectionists do not accept the symbolic form of these representations and talk about subsymbolic forms of representation.

More radical are the critics coming from theories of complex dynamical systems. Authors like Moravec (1988), Chalmers (1991), Van Gelder (1997), Brooks (1997), Varela, (1988), Winograd and Flores, (1986), Petitot (1985), Scott-Kelso (1995), Franklin (1995), Globus (1992), etc. have refused this representational model. Like the precedent critics they maintain that the concept of representation is an inadequate tool for describing dynamic informational systems.

"Representation is the wrong unit of abstraction in building the bulkiest parts of intelligent systems. (Brooks, R. A. 1997: 39 6)

"It is the concept of representation which is insufficiently sophisticated" (Van Gelder, 1993, p. 6)

"We are not building representations at all!" (Thelen and Smith 1994, p. 338.

But as we shall see, in spite of differences in terminology, most of the contemporary information processing models, be they static or dynamic, symbolic or not, rely on similar conceptual structure that are highly reminiscent if not identical to representational model. But they differ in the architecture of the dynamics of these representational structures. Hence a debate is born. It is polarized around the representational or non representational nature of information processing. But, like it or not, such a debate is basically a semiotic one. And in this paradigm one could ask if IPS are not,in fact semiotic processing machines?

2-Information and representation.

What is a representation? How does it relate to information. Contemporary theories often prefer the concept of *information* to the concept of *representation*, seeing there a strong theoretical difference. But one should remember that these two concepts have a common philosophical origin. Indeed, the concept (not the word) information is not a new concept in the field of cognitive theories. It was already at work in the medieval philosophy of mind. In the scholastic Aristotelian tradition, the soul or "anima" was defined as an agent that in its relation to the external world undergoes a cognitive ("cognitio") process. It had the capability (facultas) to transform a physical external object by changing its "materia" into a "forma". The cognitive process was seen as one that *renders present* an external object in the agent but in a new *form*. It "re-presents" it. The cognitive agent is then said to be "in actu informata". Hence, being "informed" for an agent " is to possess a re-presentation of what is present outside of it. That is why for a cognitive agent the type of processing it can realize can only be on representation, that is to say a *"informatio"*... And Poinsot, talking about cognition, formally identifies representation and information.

> *"[...] est uius representatio et exercitium significandi informando fit.*
> *"*
>
> *(Poinsot: I, q 1, 655a, 47).*

As one can see, in its medieval sense, *in-formatio and re-presentatio* share common properties. And one of them surprisingly enough, it is not necessary for them to be symbolic. It is only in the theory of abstract *concepts* that a representation may take a semiotic form, i.e. become a *signum*. And a *signum* is not necessarily a symbol. The thesis that representations are symbolic only comes later in philosophy. It is with Descartes that representations become symbolic entities and are identified with ideas. It is not surprising then that our contemporary understanding of information processing systems includes reference to « representations ». Although contemporary models of IPS differ in terms of vocabulary, we find in all of them this common foundational structure. In this very general perspective, all information processing systems manipulates not the external object present outside of them but something akin to their own internal structure. In this sense, all IPS manipulate information that is a type or other of representation.

In fact, the use of the concept of representation is not wrong or incorrect. It is just very general. It only says that what a IPS manipulates is not the external objet that is present out there but something inside it. In this sense, a theory of representation for IPS is neutral in regard to the form this internal form will take. It does not say whether it is iconic, symbolic or causal.

3-Three implicit theses.

In spite of a vocabulary difference and because they call upon a general conceptual framework, all models of IPS must commit themselves to three implicit thesis : a semiotic, an ontological an epistemic thesis:

3.1 -the semiotic thesis.

A system that manipulates information implies that what it manipulates is in some way or other in relation to something else. Most of the time for an IPS, having information implies that it has rendered internally present (re-presented) what is present outside of it. In other words, an IPS processes something that is not autonomous it itself, but something inside of it that is also in relation with what is outside of it. In classical semiotic theory, there are at least two ways this special relation can be though of. Firstly, it may be realized in a stipulative manner or by convention. This type of re-presentational relation is classically called non-natural and its prototypical form is symbolic. This is often encountered in artificial information systems where a programmer stipulates what are the "representation" the systems may possess. Secondly this representational relation can be realized through some causal process. If so, it is classically called natural and its prototypical form is, in peircian terms, *indexical*. Natural systems realized this through transducers that causally relates them to what is outside of them, i.e. their environment.

It hence follows from this distinction, that to be re-presentational it is not necessary for a system to manipulate symbols. It could be representational if it manipulates only indexical or causal representations. What the classical concept of representation stresses is only that there exists a means by which the environment is present *in a new mode* (or in a new form) in the system. This is often maintained in models of information processing system by distinguishing between data and information.

> *I think of information as not existing out there in the environment. Information comes into being when minds process sensations."Dawkins 1987 p 5*

In other words, being representational does not imply being symbolic! Indexical and causal informational relation are re-presentational. In this sense, information is but a new name for a causal representation. This is a position that has been taken by Peirce and repeated lately by Drestke

> *Talking about information is yet a third way of talking about the fundamentally important relation of indication or natural meaning. Dretske: 1982: 58*

Hence, an information or a representation defines the mode under which the exterior world is present in a system. An information or « representation » is what comes in the processing unit, but originates from outside of it and in another form. In the symbolic type of representation the formula « stands for », gives meaning to symbols because they are grounded in stipulations or in conventions. In the indexical type, the same formula only means that what is present in the system and is the object of manipulation is causally related to the exterior of the system. In this perspective, the concept of *information* and the concept of *representation*, do not offer much theoretical difference.

3.2-the ontological thesis.

The second thesis is an ontological one. It maintains that a representation exists in some form or other and creates internal states in the system. In semiotic terms, they are it's internal state of affair and constitute the *Umwelt* (Von Ukûll, 1940) of the system.

This ontological thesis originates from the fact that information or representations are quantified. IPS models say that they manipulate *one or many* of them. This means that they are committed to recognizing them a type of existence. In fact all models of IPS implicitly defines an identity criterion which is necessary for them to recognize when two representations or information are identical. That is, under what conditions are they similar? Two information are said to be identical if they offer some similar form or can be recognized as falling in an equivalent class.

For some models of IPS, representations only have logical properties (Fodor); for others, they are strictly semiotic (Peirce, Eco) or symbolic (Newell and Simon, 1976). And they should be distinguished from their material properties. In this case, the identity criterion relates to the functional operations that can be applied to information. Two information are identical if they possess the same functional properties. Other models of IPS understand the existence as purely physical (Churchland, 1989, Varela 1988, Petitot, 1985 Penrose,1994, Van Gelder,1997 etc.). Information in these models should not be confused with its functional structure. The identity criterion pertains to the physical nature of the transformation that can be applied to information. Two information are said to be identical if they possess the same physical properties.

But in both types of models, it is not always clear if there is really a difference between the functional and the physical properties of information. Indeed, one must not confuse the *functional* or *physical* nature of a representation or an information with its *material* nature or its vehicle or carrier. Indeed, the material carrier of an information is something very different from its functional or it physical structure! For instance, if a system is presented with two identical information at different time, it must be the case that they are materially different. Still they may be functionally or physically identical! Functional structure depends on the operations the constituents have in a system. But this is also true for physical structures. The epistemological question is then to find a real difference between a functional structure and a physical structure.

An IPS system does not deal with information as it does with the carrier of information. For instance it would say that a robot vacuum cleaner manipulates informational state about dust in a very different way it manipulates the dust itself. Storing information about dust is not the same as accumulating dust in its bag. An infoglut dust robot is not necessarily a dusty robot! And vice versa!

So, ontologically, a representation always has a material carrier, but this does not suffice to explain its structural properties be they described in functional terms or physical terms. But whatever IPS model chosen it is always committed to an ontology.

3.3 the logical thesis.

The third thesis defended by all information processing models pertains to way the system relates to the internal state created in it. The thesis maintains that an IPS does not only create informational states, it operates on them in a certain way.

> *[Information is] anything that can undergo dynamic changes and / or can be transmitted from one system to another. (Young, 1987: 19)*

If the ontological status of information is of the symbolic type, then an IPS will operate on them in a logico symbolic fashion. This means that the transformations of the internal states created are rule-governed. And hence they may be syntactical or compositional and are usually linear or sequential. In classical philosophy of mind, this type of relation of the system (mind) to its representation will take the form of epistemic attitudes and what is allowed as transformations on attitudes contents are logico linguistic transformation (Fodor, 1975). But if the information or representations are not of this ontological type, the operations may be quite different. If for instance they are natural or indexical, they are said to be submitted to physical laws? But still what are physical laws? Are they mechanistic or quantic? Are they probabilistic or not? Is substitution of identicals always possible in these states?

Whatever position taken, the thesis maintains that the operation on informational states are different from the states themselves. And an informational processing model must commit itself to a type of possible operations it can apply to the informational states. Let us now study more in detail the nature of these “logical” transformations.

3.3.1Computational transformation.

A main characteristic that these transformations are usually given is their computability. Indeed, when IPS manipulate information they are said to compute it. But one may ask if the concept *computatio*n the right one to explain the dynamics of information processing. Are IPS necessarily computational systems in the Turing machine sense? The answer to this question is not as clear as one may think.

If we analyze more precisely the various type of IPS, what is basic is not the fact that there are computable machines but the fact that they apply transformation to their internal states. After having accepted their input all IPS are said to transform states of information into other states. In the case of symbolic systems these states take the form of propositions which are transformed "discreetly" into other propositions through some types or other of rules (usually inferential). And in non-symbolic systems, the states take the form of configurations which " smoothly" transform one into the other through some thresholds or constraints. But the hard question is : Do these transformations have to be computable transformations in the Turing sense? The only answer we could give here is that from an ontological point of view, it is quite clear that many systems do not require that transformations take the form of rules which are typical of symbolic systems. There exist many non symbolic systems that realize transformations without such rules. Should these systems be called non computable? And hence they would not be information processing systems. Inversely, from a semantical point of view, one may ask if the only definition of computation can be given in terms of inferential rule and decidability. If so, all dynamic system that are not symbolic are non computable systems. Still, intuitively speaking, it is difficult to deny that such system do " compute" because their transformation process is not inferential. Maybe, a revised definition of computation may become necessary. Some authors even believe that, from a syntactic point of view, the difference between inferential rules and a physical transitions rules is not that easy to identify. (Gardenfors1994; Setiono et all, 1996) In this sense, physical transformations would all be described by inferential rules and vice versa.

3.1.2Classification transformation.

Another important property of IPS is that they privilege a special sort of transformation. They change the type of the states of the entities they manipulate. Indeed, the transformation of states in IPS are not just modification of material carriers. For if it were the case, a digestive system would be an IPS. Here, something more is realized. Indeed, the controlling devices operate as a partition of the inputs into some equivalent classes. Accepting an input always require a criterion that identifies the class to which each input should belong. In other words, information processing always applies classification of some sort to its inputs. Here lies an important difference between a purely material processing and an information processing. An IPS always realizes some sort of pattern recognition. Whatever enters an IPS does not simply transits through it. It is accepted if it is an instanciation of a class. And because of such a type of operation that it may cause a reaction in the whole system. Chalmers (1991) even identifies information as patterns. This means that the input, when it enters an IPS is but an instance of a class. In logical terms it is an element type input. What is at the output is not the same object. It has been classified (intentionally or extensionally). And what comes out of the system is of another type. Hence a IPS is a classifier.

3.4 IPS and the three thesis

These three thesis- the semiotic, the ontological and the epistemic are the main characteristics of a representational theory of information. And we hold that they are at work in the various models of IPS, be they declared symbolic systems or non symbolic systems. Indeed, all IPS do not manipulate the external object itself but a substitution of it. Secondly in all IPS, this substitution creates one or many of internal states akin to the nature and structure of the system. And finally, all IPS apply some type or other of transformational operations on these states. Hence the representational theory implies subtitutivity, quantified existentiality and transformationality.

Often these three theses go unnoticed and are entangled in a undifferentiated discourse. For instance, they are eminently present in the so called « mentalistic » or representational theories of information (Fodor 1975, Johnson Laird 1988, Pylyshyn, 1984, etc.) In these models, the semiotic relation is symbolic, the ontology is made of discreet states, and the transformation are logical. These theses are also present in sub- symbolic models of IPS (Smolensky,1988xx, Rumelhart et all 1987.) Here the semiotic relation is essentially causal, the ontologies are distributed states, the transformations are non discreet.

But it is also more and more evident that these three theses are to be found in these models that explicitly refuse the concept of representation. (Scott-Kelso 1995, Varela, 1988;Van Gelder, 1997; etc.). For even if they prefer the term information to that of representation, they still have to answer the question typical of representational theories such as 1) how is information related to the exterior of the system? 2) what is the ontological status of these information? 3) How do they operate on these information? A non representational theory of information processing would have to deny commitment on these three points.

Still, there exist such machines. For instance, a vacuum cleaner is a non representational processing system. The internal object (dust) it processes is not a substitution of the object outside of it. The internal state of this object is identical to the exterior object. The operations apply to these object only change the spatial location of the object: At the end of the process the dust is in a small bag! No one seems to maintain that such a machine is an information processing system.

4 -The architecture of basic representational systems.

A close study of the structure of various models of IPS reveals that they all contain in fact two different levels of "systems" one elementary, the other complex. And both levels do not operate in the same manner. The “granularity” or the “resolutionality” of the constituents may be more and more refined and precise, but still, they all distinguish the properties of the elementary constituents from the combination of these elementary constituents into complex systems.

The elementary constituents:

All IPS contain elementary constituents. They may vary in vocabulary and may be called *modules, granules, morphs, atoms*, etc. And they may be found in neurons, chromosomes, cells, etc. But whatever is their material carrier they are usually described by the main following features. They are basic machines that establishes a specific controlled correspondence between the inputs received and outputs produced. This can be shown in the following schema:

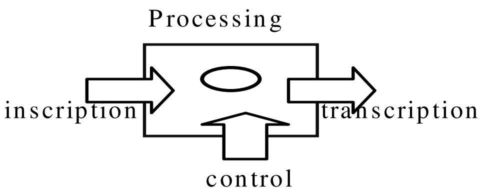


FIG 1

This basic "abstract" machine contains:

a) an *inscription* device -b)a *processor* of some sort c) a *controller* d) a *transcription* device.

The *inscription* device (transducers) transforms the input into some entity akin to the system. An internal state is thus created. The system is then said to be “informed”. The *processing* unit has these states go through tranformations. The *controlling* function defines the degrees of freedom of the process it self. The *transcription* unit transforms the results of the processing into a form that another system may receive.

This schema is very general and classical. It is to be found in all models of information processing. In classical cybernetics and artificial models, it becomes a Turing Machine, (Ashby, 56, Turing, 1937, Von Neumann, 1957, etc.) or a grammar, a production system, etc. This schema is also found in dynamic models. For instance, in the connectionist models each neuron is basically a Turing machine (Franklin & Garson, 1989). In genetic models, each basic operation (mating, mutation, reproduction, selection etc.) is also a Turing machine. In fact, in all emergent and dynamic systems, there are usually some forms of basic constituents that are taken for granted, but if studied more precisely are often minute automata. And as we shall show later, it is not at this level that a real difference exists between these dynamic and emergent models and classical automatas.

But what is important to notice is that all these elementary “ machines” are always determined by some controlling parameter exterior to them. (In fig. I the control arrow originates from the exterior of the system.) This aspect of “ automatas” is often neglected in their descriptions, mainly when it takes the form of a black box. In other words, the degrees of freedom allowed to the processing device are not a property of the states themselves neither of the processing device, but are always imposed on them by an exterior factor or agent. In the symbolic systems, the controlling devices are rules and grammars and they do not originate from the states nor from the processing device. They have to be either stipulated or learned. This is even more obvious in non symbolic systems where controls take the form of parameters, thresholds, limits, etc. Here too, they are exterior to the states themselves and to the processor. It is because of this “externality” that these elementary systems will have to be in relation with other systems.

The preceding schema can be translated into a categorial description that defines this elementary process as the application of an operation O_i to its arguments $(e_i,..... e_i)$, with the value its delivers e_k..this gives the following categorial expression:

A basic IPS is **: <O_i (e_i,..... e_i), e_k >**

That is, the basic constituent of IPS can be seen as a transformation operation C applied to entities *e* (input) of categorial type *i* and produces entities *e* of categorial type *k*. (output).

What translation renders more evident is that a precise definition of the criterion of identity of the operation O_i must be given so that it can be applied to its arguments. In so doing, we discover that the criteria are not the results of the system itself but are given to it by some exterior intervention (a programmer or another system).

In semiotic terms, this schema can been understood as a basic " semiosis" machine, that is as a system that transforms inputs of some type of state and then has them go through controlled transitions where new types are created, and then ultimately transforms them into objects that another semiosis machine can accept. The operation does not have to be digital, discreet, symbolic or sequential. They may be parallel, non symbolic. All what is required is that they be parameter controlled. (See Meunier 1998 for an example) In category theory, this implies that there exist adjunct operation.

Complex information processing systems.

The preceding schema has presented the elementary constituent of all IPS. But such a basic constituent one cannot describe a complex information processing system. Even the simplest computer game could not be explained by such a schema. For real systems are not built out with one single such basic constituent but out of a multitude of such basic constituents. They all need to be connected to some exterior controlling parameter. A connectionist system for instance, is formed out of myriad of basic neurons. A brain depends on millions of basic cells. And each of these basic constituent is itself determined by some exterior parameter (for instance, its thresholds, a delta rule). This is why so many models of complex IPS must define the relations among these elementary constituents. How are they organized in order to manifest complex if not real information processing?

In this paper we will study two main types of hypothesis about the nature of the combination of these elementary constituents into complex systems. The first proposes to see complex systems as a multilevel and hierarchical structure and the second sees them as multilevel but where the combinations is dynamic.

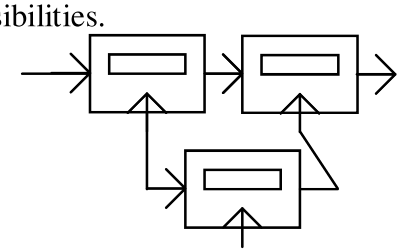
Hierarchical architectures.

The first type of architecture modeling the interaction between basic constituents is discreet, multilevel and hierarchical. Examples of these models can be found in philosophy (Fodor, 1975, Commins, 1989, Pollock 1989) psychology (Johnson Laird, 1989), artificial intelligence (Newell and Simon, 1976) and robotics (Albus and Meyster, 1996), intelligent agents systems (Bradshaw, 1997). These models see information processing as the interaction between various types of discreet and autonomous elementary IPS. And complexity emerges from the interaction of this variety. There exist many models of these interactions. But we can distinguish in most of them the following main types.

1) First, there is usually a *perceptual* and *effector* level type of constituent where sensory input and output are processes. This allows the direct causal relation of the system to its environment. 2) A *praxiological* level assures the manipulation of goals and motives for effective behavior. 3) A *normative* level manipulates parameters to which the system must conform. 4) An *epistemic* level insures the effectiveness of the system it self. 5) The *Ipseic* level allows some type or other or self identity for the system. 6) Finally, some systems will include conditions for learning the potentialities of these modules. Naturally, many variants are possible. [2]

What is important to underline here is the two following features. First, in this architecture, the levels are all interdependent, but most of them are not organized in a grammatical or syntactical manner. This means that the interaction of the various levels are not necessarily compositional or rule-governed, that is, are organized by a Turing machine. For instance, a robot could perceive something at the perceptual level and this in turn could cause a movement of its effectors. The relation of these two events is not dependent on a logical rule. It is not a *necessary* sequence of events. For it could be learned in a associative manner and only when so learned could it become a rule-governed behavior. This point is important, for it shows that, complex IPS models do not defend a compositional structure. Their basic constituents may be a Turing machine but when combining these elementary constituents, some models abandon the compositionality that was previously so essential.

Secondly, there are various types of levels in these complex systems because each does not entertain the same type of relation to the other parts of the systems. This renders them logically different. For instance, the perceptual processes relate the system to the environment. The praxiological ones touch upon the interaction of the system with goals. The normative ones may relate to parameters. The epistemic ones may operate on the effectiveness of the components of the system itself. The ipseic processes may give the system a self identity. In others words, in this approach an IPS complex system cannot be only a conglomerate of elementary processes. Each level seems to depend on the other to realize its own possibilities.



They often are the source of the controlling parameters. It is in this sense that it is hierarchical. This point is also important, for it show that the complexity can not relies on simply having the system relate to its environment. It must also possess elements that operate on the system itself. This contradicts IPS modeling that tends to reapply the "perceptual level " i. e. the level that relates the system to its environment as the prototype of all other levels of IPS. In other words, complex

[2] One may see these levels as very classical, they are isnpired by philosophical and semiotic theories of cognition (Aristotle, Aquinas, Descartes, Kant, Husserl, Peirce,) and contemporary ones (Dennett, 1978; Pollock, 1989; Clark 1993, etc.), These philosophers have repeatedly postulated them as necessary if not sufficient conditions for systems to be of the cognitive type.

systems are not the simply " complexification" of perceptual type of level. One cannot simply complexify a perceptual machine and upgrade it to a complex IPS.

4.1 Associative Architecture

More and more models of IPS systems present themselves not as mega hierarchical but as a complex dynamic systems. For instance, neural networks are not presented as a unique super neuron but as a complex associative interaction of neurons. Chaotic models are based on non linear interactions between various states of the system. And hence many models claim that the structure of complex systems cannot be explained in terms of hierarchy. Their organization is non discreet and non linear. They are said to be dynamical or emergent

But if we compare the architecture of these systems with the preceding one, we discover some important similarities. First, as said above, they all rely on some basic constituents (neurons, genes, etc.) some of which receive input, others activate effectors. Secondly, they are implicitly multilevel, (cf. levels of neurons in connectionist models, levels of operations in genetic algorithms, etc.). For instance, Churchland and Sejnowski (1992) espouse a commitment to the hypothesis that "emergent properties are high-level effects that depend on lower-level phenomena in some systematic way" Thirdly, parameters control all of them (weight, thresholds, activation functions, etc.) Some even have monitors of the systems, etc. In fact, one could see that these dimensions are instanciations of the perceptual, effector, normative, epistemic, and ipseic levels defined for the preceding architecture.

But these models present also two important differences. Firstly, the interaction of the these modules is usually associative and are formally modeled through probability or statistics. That is the consolidation of the relation depend on either reiteration or cooccurences. They are not deterministic in that sense. But once a state is stabilized, these systems seem to behave exactly as a rule or a parameter governed system. Hence, the behavior of the whole system is not necessarily explained in terms of rules or grammar

Secondly, these architecture relate to a hidden dimension not always explicitly present in the first architectures. Indeed they are all time indexed. That is, they include not only a model of the information path but also the patterns of transitions of the states of the system. And it is because of the inclusion of this time index that they can describe dynamic processes.

5-Conclusion

In semiotic terms, one could say that both of these multilevel architectures relate not mainly to the traditional concept of sign but to the less known concept of semiosis. Semiosis, at least for Peirce, pertains to the dynamic aspects of representational systems. It is a categorical process although not necessarily a syntactic one. Most of all it is a pragmatic one.

In formal terms, we can say that these multilevel systems, neither the hierarchical or the dynamic ones are generated by some grammar or Turing machine. If we were to compare them to something linguistic or logic we would have to say that these structure, are more like texts or proofs than sentences or formula. As one knows, in language, only sentences or formula are rule governed not texts and proofs (even if many authors have hoped that it would be the case). Proofs and text cannot be generated by grammar.

From a logical or functional point of view each two preceding types of models give a different answer to the question of how the numerous constituents in an information processing systems are organized into a coherent whole. The first type of architecture maintains that the structure of interaction is hierarchical. The second maintains that the interaction is associative or probabilistic.

It follows that complex information processing system can be representational that is semiotic without being symbolic and with a syntactical structure. It could be purely associative and probabilistic. Hence a representational system can also be dynamic systems.

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