From Semiotics to Computational Semiotics

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ABSTRACT: Semiotics is a branch of human sciences, which studies the science of signification and representation, involving mainly the phenomena of cognition and communication on living systems. This interconnects somewhat with the study of intelligent systems, where some of the objectives are the study of the phenomena of cognition and communication, but now explicitly under the scope of artificial systems. Computational semiotics corresponds to the proposition of a set of methodologies that in some way try to use the concepts and terminology of semiotics, but composing a framework suitable to be used in the construction of artificial systems. Despite computational semiotics is a new inborn science, there are currently some important contributions that despite still not complete and definitive, help us in understanding the nature of semiotic processes and allow their synthesis and implementation within computational platforms. In this work, we explore one possible pathway along a set of ideas evolving around, which proposes one way of gathering the transition between traditional semiotics and computational semiotics, making it possible to synthesize semiotic systems by means of artificial computing devices.

1. Introduction

Semiotics is more than Peircean Semiotics (Peirce, 1960). Since the greek philosophers up to the 20th century thinkers, many great minds have faced themselves with the questions of the sign, how it works and how it can be represented (Noth, 1996; Noth, 1998). Different models for the sign had evolved in history, some of them better elaborated than others (Noth, 1995). For very much time, though, the questions around semiotics were restricted to the human sciences domain - philosophy, linguistics, arts. More recently, new sciences appeared interested in the semiotic background. Marketing and publicity, journalism and the whole field of "communication" in general become interested in it. But, the real (and possibly strange) new people that started to be concerned with semiotic issues are people from the called "exact sciences". How did this interest start from ? Since Von Neumann published his first sketches delineating the computer (Von Neumann, 1958; Von Neumann, 1966), people started to wonder if this new machine would not be possible to reproduce human intelligent behavior (Albus, 1991). Since then, the whole field of artificial intelligence had emerged. As artificial intelligence as a field was not able to explain most parts which constitutes human intelligence, new sub-fields were created. Among them, it is worth to notice the fields of soft computing (Zadeh, 1994) and computational intelligence (Zurada, 1994), where a lot of insights given from biology were used to make machines work in a more intelligent way. These sub-fields are still under development today, but there seems to be also something missing. More recently, people from computer science and engineering started to look at semiotics as a source of insight in order to build more intelligent systems (Gudwin, 1996; Meystel & Albus, 1996; Meystel, 1996; Prueitt, 1999; Pospelov, 1991; Doeben-Henisch, 1996). In a first step, independent thoughts started to proliferate, trying to arrange this strange combination of semiotics with intelligent systems. Most of them, realized that semiotics, in its current conceptualization, was not fully adequate for this junction. This leaded to efforts in order to grow, inside semiotics, a branch where the main concern is in how semiotics can be used to build systems able to perform semiosis and, due to that, evolve intelligent behavior. After a set of international conferences dedicated to the junction Semiotics and Intelligent Systems, a group of researchers started to collect and summarize the results obtained so far, and denominated this topic of research as "Computational Semiotics".

So, as for today, Computational Semiotics can be viewed as a proposition of a set of methodologies that, in some way, try to use the concepts and terminology of semiotics, but composing a framework suitable to be used in the construction of artificial systems. The main issue in this case is the intention to synthesize semiotic systems and implement them within digital computers.

Despite being a new inborn science, computational semiotics seems to bring important contributions that, despite still not complete and definitive, help us in understanding the nature of semiotic processes and allow their synthesis and implementation within computational platforms.

Particularly in this work, we will try to bridge the gap between standard semiotics and computational semiotics, exploring one possible pathway, along a set of ideas evolving around, which proposes a set of foundational concepts that, we hope, will be helpful as a background for this new science. We would like to see this as a mental exercise, where we play with concepts which does not match perfectly in a first glance, due to their human against technological origins. Our challenge is to make a fine-tuning between concepts originally aimed to apply only to human or biological beings and make them fit too for artificial man-made systems.

2. Semiotics: A Tool of Analysis

One of the first problems we are faced with is that semiotics, in its standard conceptualization, is a tool of analysis. Its main goal is to understand and explain semiotic processing already happening in nature. Usually, it starts from the premise that there is a semiotic being (interpreter), that can be a living organism (in the case of biosemiotics), or the own human being (when considering human semiotics), and then it tries to analyze the processing of signs within those semiotic beings, and model them by means of using different classes of signs and sign-processes.

But these semiotic beings are already there. We do not need to build them up from scratch. What we are considering is radically different. We want to create new systems, and that in a way where we wish to synthesize the sign processing that happens naturally on organisms or on human beings.

In order to do that, we have to consider many questions that still don't have an easy answer. For example, should it be possible to use the same conceptual background in order to synthesize new beings (systems) performing the same semiotic behavior as living/human beings would do ? Or will we need to develop further the current concepts in order to use them ? Or will we need to develop new concepts in order to do what we want ? What would be the challenges hidden in such an endeavor ?

Basically, the greatest problem, simply put, is that when considering artificial beings, the things are not already working. And our challenge, then, is to put them to work ! Instead building hypothesis on how sign processing is performed, we have to design how they are going to work. And then, normally, a great number of hidden problems start to appear.

For example, what are the basic entities involved in the process of semiosis ? It is not a matter of conjecture, like in standard semiotics. We have to design them. Otherwise, our system is not going to work ! And more that this ... we need to design them in a way it can be produced within a computer.

We can not just say that when processed, a sign generates an interpretant related to an object in the interpreter's mind. We need to specify the mechanism by which signs are interpreted. We need to describe in what way a sign is going to generate an interpretant in the interpreter, related to an object. When trying to explain how this things work in a human mind, in traditional semiotics, there are a lot of intermediary steps that are generally not considered. Just to name a few: how, from a scene given by a video camera, we discover the objects involved into this scene. A human being, seeing a scene, naturally is able to decompose it into a set of objects, positioned in their places. And each object can then act as a sign of another object, for example. For a computer, we can't just do the same thing. A bitmap image is only a bitmap image. To transform it into a set of entities, we will need further algorithms. We will need to formalize more things and detail how do they work.

How can we talk about signs, if the system is still not aware of objects ? An object must first be modeled in order to be referred by another sign. So, before talking about signs, we need first to establish what are the basic modeling entities we are going to use in order to describe the world, and how those entities will be encoded within our artificial systems. And this is a place where a lot of confusion comes on. People start making a semiotic analysis of this encoding mechanism (yes, it is a semiotic process too!), and start confusing the signs in the sense of us, human beings, understanding the artificial system, and the signs in the sense of artificial system, i.e. things that are signs to them. It is very easy to loose our signic reference when performing such a task. Things that are signs to us, trying to understand them, are not necessarily signs to them.

And, the dreadful question: ... are computational devices able to carry on all sign-processing capabilities that we, living/human beings are able to perform ? And, if the answer to this question is negative, what are we missing when using only computational devices ?

3. Semiotic Synthesis : The Basic Foundations

In this session, we will try to set up the basic foundations in order to describe semiotic synthesis. Our goal is just to set up a generic scenario, in which semiotic synthesis is going to be discussed. We do this, in the hope to get clues on how semiotic processes really happen in a natural interpreter. This is absolutely necessary if we want to implement artificial systems performing semiotic behavior. Our framework will need to allow the implementation of a computational version of semiotic processes.

The terminology we are going to use is very much related to standard semiotic terminology. So, we are going to talk about signs, objects, interpretants, interpreters, signals, and would also be making extrapolations in order to include icons, indexes, symbols, tones, tokens, types, rheme, dicent, arguments, firstness, secondness, thirdness, etc. We are not going to make these extrapolations now. We expect to address them in a future work. But we will be trying to create a computational understanding here of what are signs, objects, interpretants and interpreters. Sometimes, this understanding is a little bit disappointing. Some people will not agree with our claims. The point is ... we can not create so generic definitions that would encapsulate mechanisms that we still don't know how they work. So, our definitions will appear a little bit limited, and sometimes naive. But this is only our first exercise, so, ... , we don't need to be so concerned with this limitation. Let's just see if the whole thing make sense !

3.1 Interpreters and Representation Spaces

Our framework description starts with the notion of an Interpreter and its Representation Space. These notions can be illustrated in figure 1.

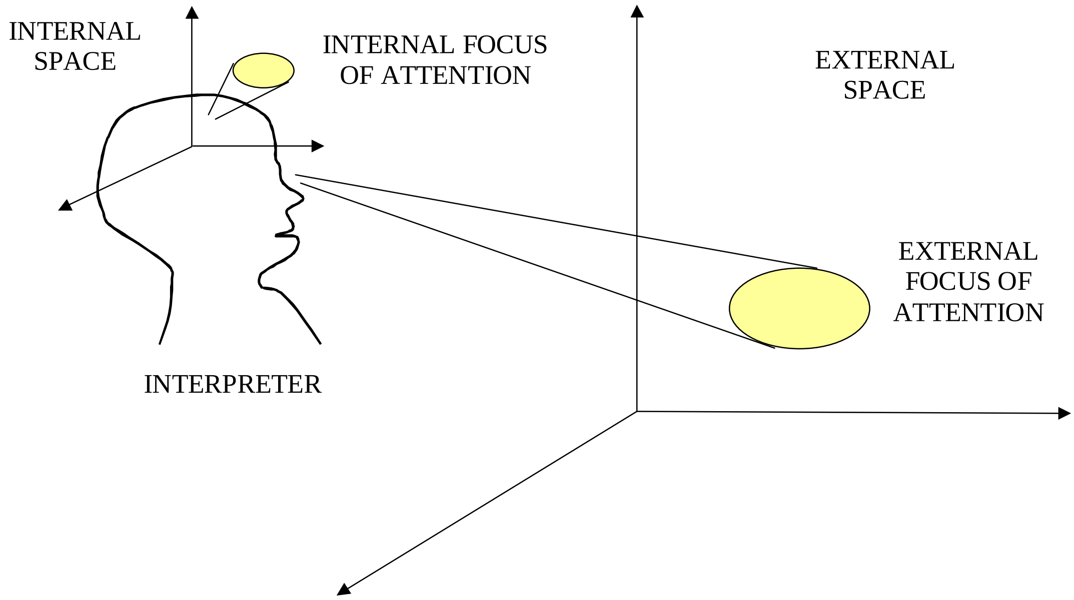

Figure 1 - Representation Spaces

The interpreter is our semiotic being, the system that will be holding the sign-processes. In a pure relational understanding of the semiosis process, some people say that the interpreter is neither necessary. But in our case, where he is exactly what we are interested in synthesize, he will be absolutely our core concept. So, the interpreter is our main object of study and our first concept being introduced.

The interpreter is immersed into an environment, where he is able to get information by means of sensors, and actuate by means of actuators. The interpreter is also able to actuate internally to itself, changing its internal configuration, if necessary. The external world surrounding the interpreter takes place in what we call the External Space. So, the external space is not equal to the environment, but is only the space in which the environment happens. For now, let's just forget the real world, and cope only with this notion of external space. The standard mechanism by which the interpreter gets information from environment is through its external focus of attention, which selects a region of the external space.

Beside the external space, there is also an internal space, localized within the interpreter, and there will appear an internal focus of attention too, that is a region of internal space that is selected for some purpose.

With those two concepts, we have some points to play with. First, like it is showed in figure 2, external spaces can be shared by multiple interpreters, but internal spaces are exclusive to the interpreter itself.

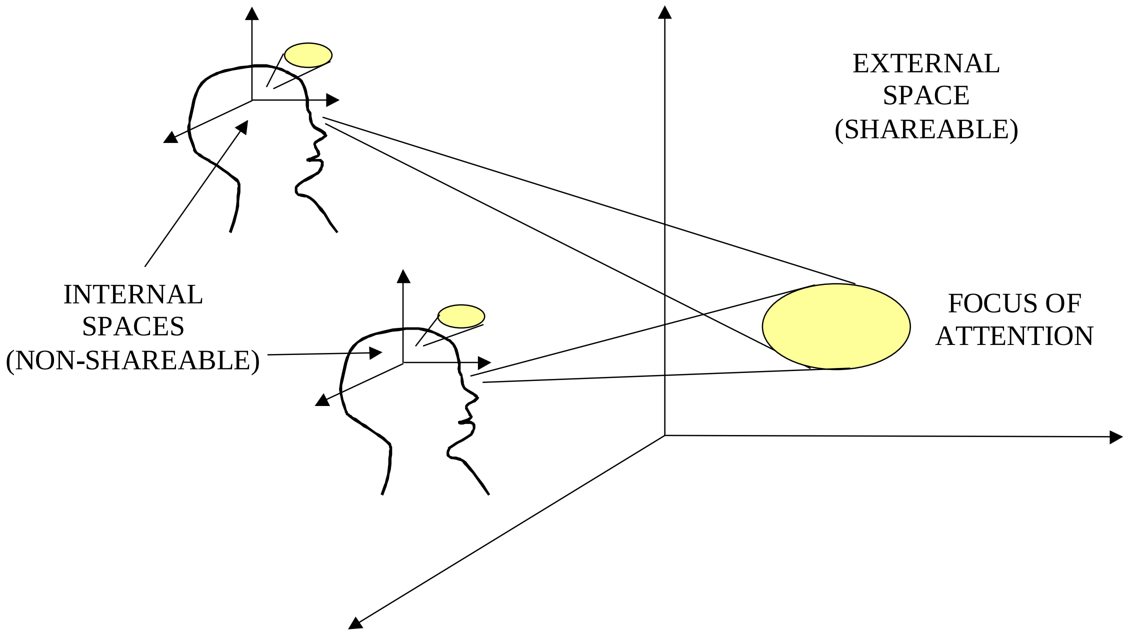

Figure 2 - Shareable and Non-Shareable Spaces

An interpreter is able to control both its internal and external focus of attention.

But all this is meaningless if there is nothing at the representation spaces (internal and external). In order to make these concepts useful, we introduce then the notion of interpreting field. This notion is derived from field theory, and basically is a function $\psi(x,y,z,t)$ (maybe an energy function, or a wave function), that to each point in space and time, determine a unique value. When we are using 3-dimensional spaces, this value is considered to be a state of the point (x,y,z), at time t.

To each representation space, we assume that there exists a corresponding interpreting field. So, we have at least an external interpreting field and an internal interpreting field. We do not necessarily consider that these interpreting fields are known. Sometimes they are really not known. In most of the times they are partially known. But we only consider that these interpreting fields really exist.

These notions are illustrated in figure 3.

From these concepts, we can infer some things. First, the external interpreting field is the real world, i.e. whatever really exists at the external space. We may assume that the external space is the 3 dimensional space we humans have the capacity to perceive. There are physical theories that try to detect more dimensions, but we will stay with the three we usually perceive, plus time. One important difference here is that we are not modeling our world as a world of particles like we humans usually perceive. For us, the real world is a giant and continuous wave function embracing all the 3-dimensional space, with a set of particularities (it is not just any function). These particularities are those that gives us the illusion that the world is constituted of things. There seems to be some rules on how points with lower energy (points where there is only emptiness) and points with higher energy (points where we detect the presence of things - being it solid, liquid or gas) and how those regions can move in time. It is obvious from this definition, that the external interpreting field is unknowable in its entirety. Interpreters are only able to know part of the interpreting field, where, at each time, its focus of attention is set up.

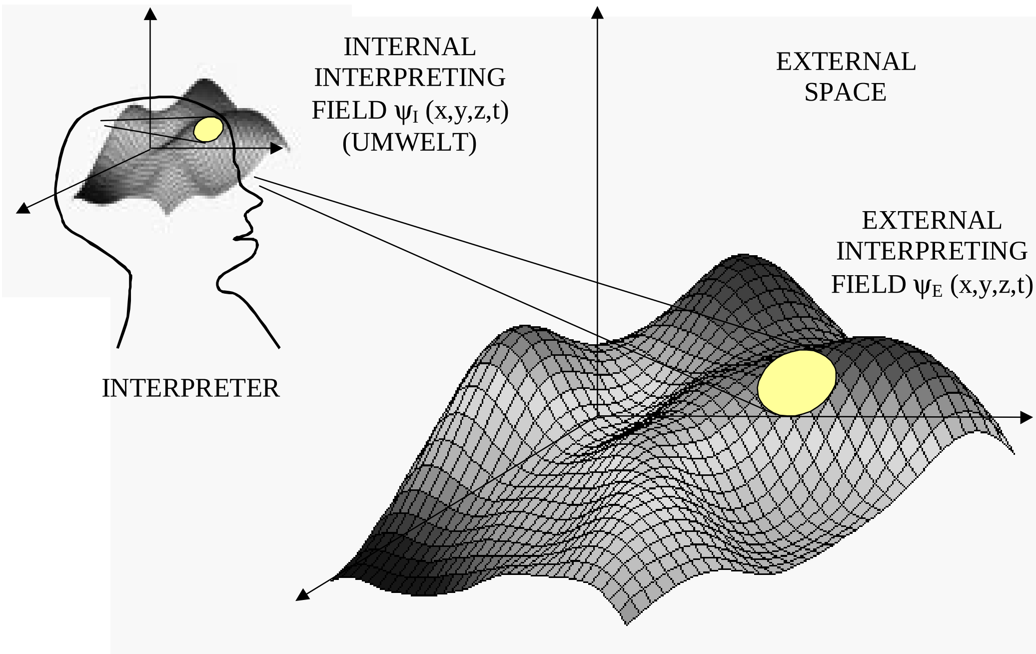

Figure 3 - Interpreting Fields

The internal space will accommodate a model of external interpreting field, by means of an internal interpreting field. Ideally, there should be multiple internal spaces (and interpreting fields), not just one (figure 4).

There should be one internal space that should hold in its interpreting field our best model of external interpreting field. This will be called the concrete space, and will be an image of our Umwelt or, in other words, our sensible environment. The other spaces, will be called generically abstract spaces. They will be used to encode abstract concepts to be used in order to reconstitute the concrete interpreting field.

In a general way, both internal spaces and internal interpreting fields will depend on the type of semiotic synthesis we are trying to model.

There are some important things we should always remember regarding those issues.

First, the external interpreting field is infinite, continuous and probably takes values on continuous sets. So, they can not be known as a whole. But, it can be known in parts, with approximations.

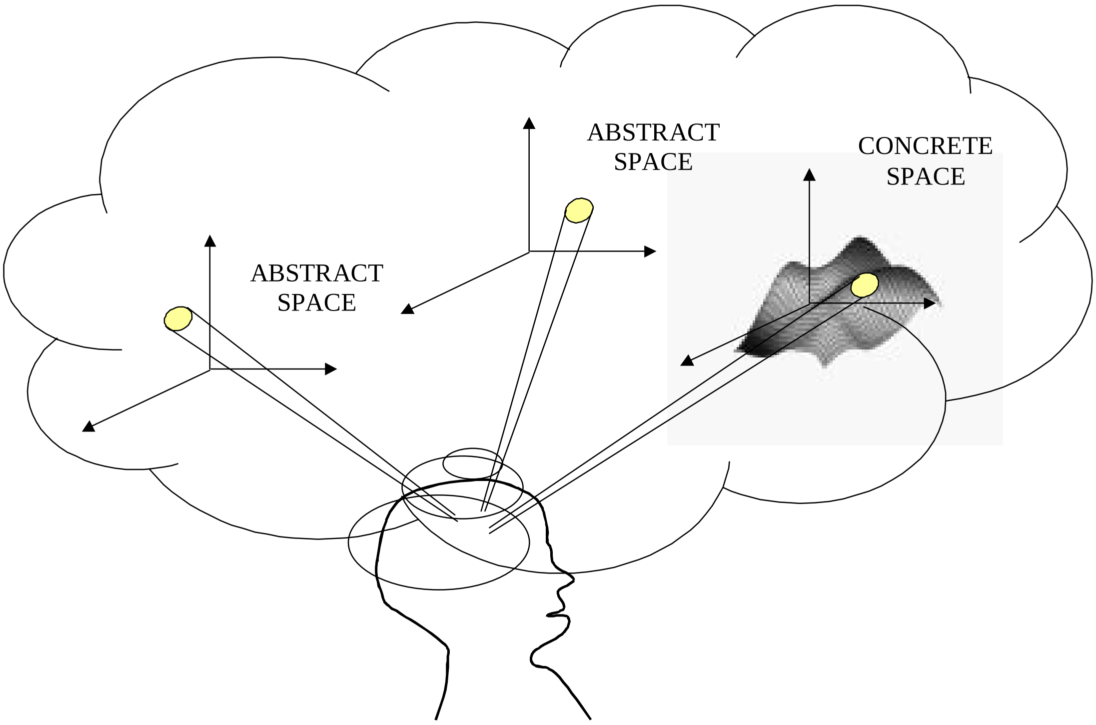

Figure 4 - Multiple Internal Spaces and Interpreting Fields

Second, the only way we are able to know the external interpreting field is due to sensors. Our sensors are established by our focus of attention. To put our focus of attention on some region of external space is equivalent to locate our sensors on this region.

Having that in mind, we are ready for the definitions to come.

4. Signs, Interpretants and Semiosis

Now there come our limited definitions for signs and interpretants.

A **sign** (in the sense of the interpreter) is understood as everything under the interpreter's focus of attention (internal OR external) that would cause an interpreter action. The possible interpreter actions are the change in the focuses of attention (internal and/or external) and/or the determination, for the time t = t+1, of a new value for any interpreting field (internal or external), at a point (x,y,z) covered by the focus of attention in that space.

The **interpretant** (in the sense of the interpreter) of this sign will be any interpreter action caused due to the presence of the sign under the focus of attention, AND/OR any change in internal and external interpreting fields for time t = t+1, caused by an interpreter action due to the effect of the sign. These notions may be compared to Peircean notions of energetic and logic interpretant, despite this comparison is not exact.

With these notions in hand, we are ready to define what would be an **external semiosis**. We call an external semiosis to the generation of an interpretant, due to the presence of a sign, where this interpretant happens at the external space. In other words, the effect of the sign is made to happen on the external space. Either by changing the external focus of attention or by changing the values for t+1 of external interpreting fields at some point (x,y,z) within the external focus of attention.

A change in external interpreting field corresponds to a change in environment. This change would be of course shareable with other interpreters that are focusing attention in the same region of external space. This change can act as a sign for the same interpreter or to other interpreters, generating a chain of interpretations.

External semiosis happens mainly on interpreters that do not have an internal space. Examples of such kinds of semiosis would be e.g. on molecules and chemical reactions. The presence of a given molecule will affect other molecule, making them to enter a reaction that is a kind of mutual semiosis. This type of semiosis happens too on very simple biological organisms that have a purely reactive behavior, didn't storing any kind of information in an internal memory.

A special case of external semiosis happens when the sign is not at the external space too, but it is in some of the internal spaces. Usually, this is a final result of a chain of internal semiosis, resulting in an external behavior.

We call an internal semiosis, a process in which the interpretant of a sign happens within any of the internal spaces of the interpreter. If the sign is at the external space, then we call this process a semiotic transduction, because an external sign cause an internal interpretant. The process in which an internal sign causes an external interpretant (which is an external semiosis) can also be called a semiotic transduction, because the cause and effect are in different spaces.

In this sense, a typical semiosis chain starts with an external sign, which generates a set of internal interpretants. Those internal interpretants become then internal signs, generating new internal interpretants. This cycle continues, until some internal interpretant become an internal sign that generates an external interpretant, resulting in a change on the environment.

5. Signals, Information, Signs and Knowledge

For use, the values of parts of interpreting fields that can be differentiated (distinguished) from other values are called signals. As signals, they only convey information. In this sense, we understand an information as the meaning of signals.

Let's get an example. Suppose that ψ_E (x,y,z,t) has a counter-domain like [0,5]. In other words, the real world has continuous values ranging from 0 to 5. Due to sensor limitations, the interpreter is only able to sense values on {0,...,5}. So, if a value for ψ_E is 2.3, or 2.2, the interpreter will understand them equally as 2. Each of these numbers is a signal, because they do not cause any effect by itself. The only thing the interpreter does is to discriminate a 3 from a 2, a 2 from a 1 and so over. Signals only describe states. They do not cause any actions.

As soon a signal start causing an action, it becomes a sign. So, signals are a species of pre-condition for a sign to exist. The information conveyed by signs (signals that do perform actions) are associated to the actions they are able to cause. When that happens (signals becoming signs), then the information is called knowledge.

We make then a strong correlation: signals-information, signs-knowledge.

The region under a focus of attention of some space, that is a sign or a set of signals, depending if causing or not a behavior at the interpreter, are then called in both cases a knowledge unit.

The basic behavior of an interpreter is then to select knowledge units both from the external and internal spaces, generating new knowledge units at the external or internal spaces.

But from what we talked earlier, the only type of knowledge units that can be acquired from the external space is of the sensorial type. And we get these knowledge units with the responsibility to create an internal interpreting field at the concrete space that is our best model of external interpreting field. The problem is that taking in account that the external interpreting field is continuous and infinite, this is not an easy task. More than this ... storing sensorial information is not efficient at all. The interpreter will spend all its life collecting this information, and there will be no room at the internal space to store it.

This implies that there should be a better way of modeling the external interpreting field. We already know that this external interpreting field has some rules of formation that can make it easy our task. And the basic mechanism that we are going to introduce is the codification of large regions of external space using the notion of entity. So, instead storing all the sensorial information got through the external focus of attention, the interpreter creates a higher level abstract knowledge unit that register the presence of entities at the external world. So, in our model, external entities are not things that do exist in the real world, but creations of the interpreter in order to make more efficient the modeling of the environment. We can't be sure if the same does not happen to us humans. But this is a philosophical issue that we would like only to suggest by now. Philosophically, it is a very controversy dispute between platonic realism and Aristotelian nominalism, which remains until today. We are here in a better position because we are talking about artificial systems, and so we can arbitrate our position here, without the controversy in saying that the same happens to us humans. Let's stay only with the insinuation that it is like that.

Now, let's continue with our description of entity. Our entities may have internal attributes, and those attributes would change in time. This creates the requirement of another type of knowledge unit, this time to model the change in entities attributes. We call these knowledge attributes occurrences. If we keep continuing the transformation of knowledge units into knowledge units, in internal semiosis processes, we will require a large hierarchy of knowledge units types. These types were previously discussed in (Gudwin, 1996; Gudwin & Gomide, 1997a; Gudwin & Gomide, 1997b).

Knowledge Units (KU's) can be of three basic types. They can be rhematic, dicent or argumentative. Rhematic KU are used to model singular phenomena happening at the environment. These phenomena can be described by words, and then we will have a symbolic rhematic KU. If we are referring to the meaning of the words, the KUs can be either indexical or iconic. If the meaning is relative, we have indexical KUs. If the meaning is absolute, we have an iconic KU. Iconic KUs can either be divided into three groups. They can be sensations, entities or occurrences. All of them divided into specific or generic. A specific iconic KU will be related to a specific coordinate in space and time. A generic KU will be related to multiple specific KUs that can be aggregated in some way. Rhematic KUs can be grouped in order to represent situations or scenes happening in the real world. In this case, this group is a dicent KU, i.e., something that has a truth-value regarding the real world. Dicent KUs that explicitly discriminate its forming rhematic KUs are called iconic. KUs that only hold a name and a truth-value (used, e.g., as intermediary steps in reasoning) are called symbolic. Both rhematic and dicent KUs are used to describe scenes happening at the real world. The third type of KU is the KU which hold the ability to transform other KUs in order to instantiate some process of reasoning. These are the argumentative KUs. They can be analytic, when the generated KUs are somewhat contained within the KUs used in the generation process. They are synthetic, if they carry some meaning that is not already in the premises. In this case, they can be inductive or abductive.

A summary of this hierarchy is given in figure 5.

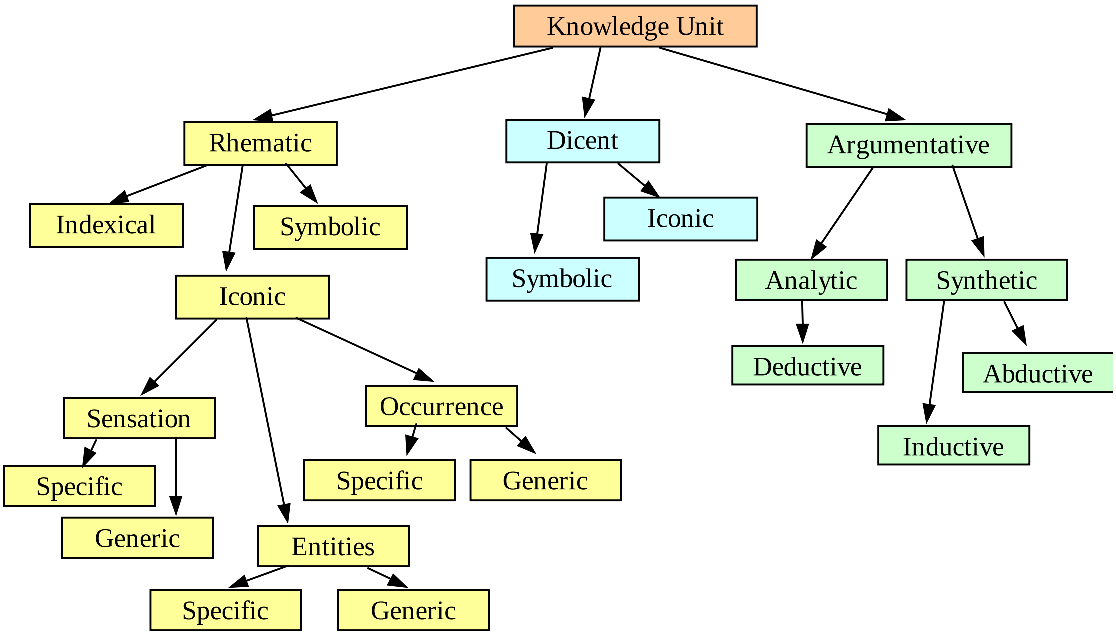

Figure 5 - A Hierarchy for Knowledge Units

6. Turning into a Computable Model

The model presented till now is far from being computable. In order to make it computable, we will need to make some simplifications. Basically, the problem is in the internal spaces and interpreting fields, which should be implementable within computers. We can't have infinite internal spaces and continuous internal interpreting fields. What we are going to do is simplifying the idea of internal space to the idea of a place, and substituting the internal interpreting fields by ranges within the computer memory. The external space continues as is, and the external focus of attention will be implemented by the system sensors and actuators. The external interpreting field is the real world. Knowledge units, at the internal spaces, will be substituted by software objects, and will be put into places, where they will be available for the interpreters.

The interpreter, as a whole, is now decomposed into multiple micro-interpreters. These micro-interpreters, will have the task to process knowledge units stored into places. Computationally speaking, micro-interpreters will be implemented by active objects (Gudwin & Gomide, 1998), and put also into places. The interpreter, will become then a great object network (Gudwin, 1996; Gudwin & Gomide, 1998).

The process of simplification of the model is illustrated in figure 6.

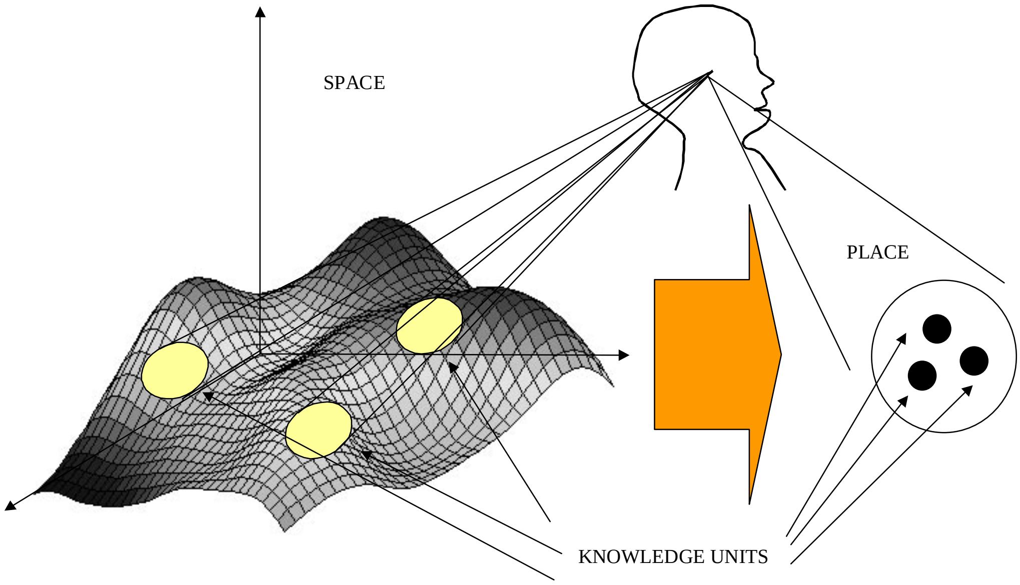

Figure 6 - Simplification of the Model

The working of these micro-interpreters is illustrated in figure 7.

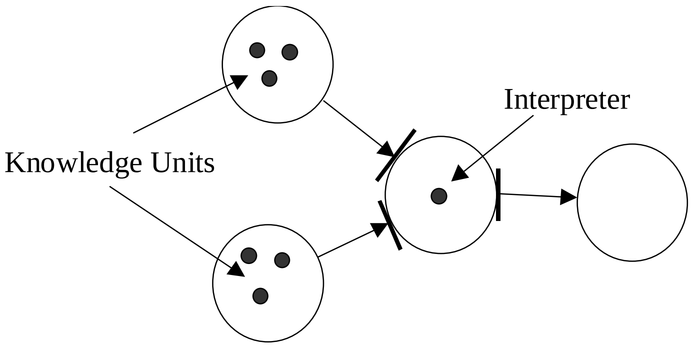

Figure 7 - The Micro-Interpreter

The micro-interpreter has three possible tasks. The first one is to choose the knowledge units to be processed. This is somewhat a simplification on the mechanism of focus of attention earlier described. For that purpose, the micro-interpreter uses a "matching function", that will evaluate the quality of each knowledge unit available for processing. After that, deciding to use a specific set of knowledge units as a premise, the micro-interpreter will execute an "internal function" that will determine the new knowledge unit to be created and disposed on the place adjacent to the interpreter's place (see figure 7). In this process, the micro-interpreter can (but not need to) destroy the knowledge units used as a premise of the argument it is implementing.

Creating a great object network, we are then implementing an intelligent system that uses a large set of micro-interpreters in order to describe its behavior. This object network can be implemented in any software language.

In order to test this idea, we have created a software implementation that is a general tool for building, running and testing object networks. This application was written in

Java language, and has its details described in (Guerrero et. al., 1999). A screenshot of the application is showed in figure 8 below. It has been used to solve some small toy problems (like e.g. the traveling salesman problem, the eating philosophers problem, etc). We are now working on an object network to control an autonomous guided vehicle that runs on a simulator. The object network showed in figure 8 is an initial sketch of such network.

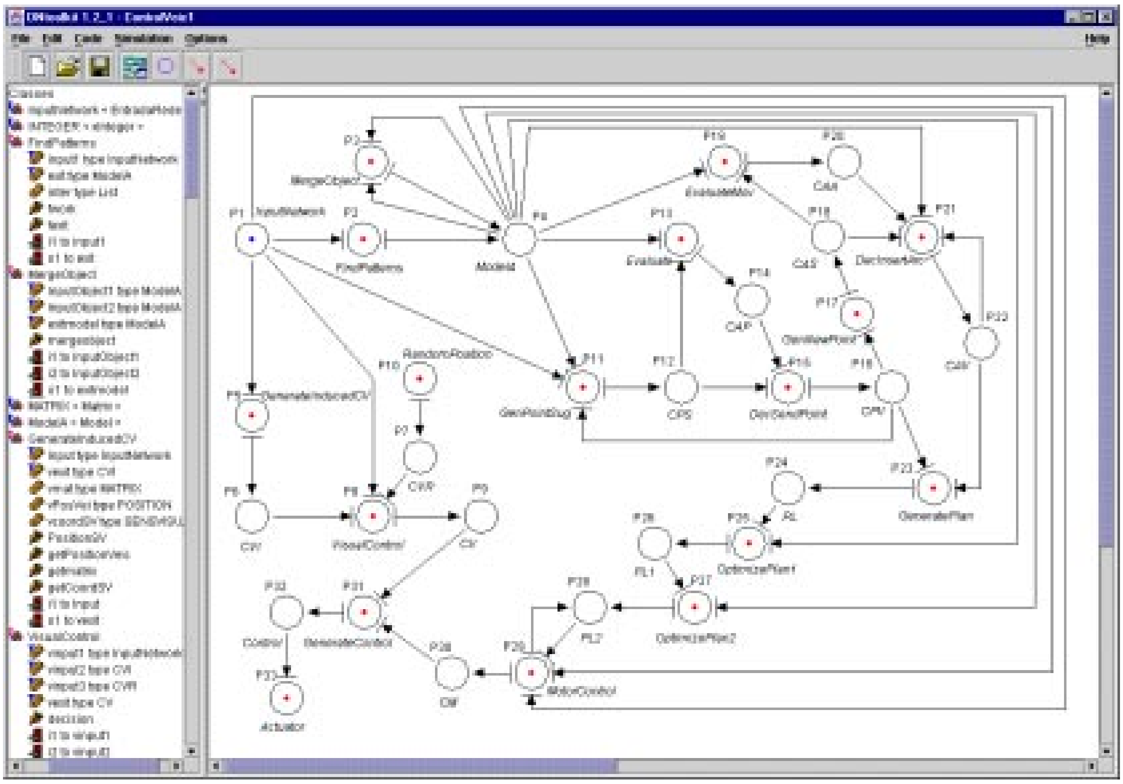

Figure 8 - The Object Network Tool

7. Conclusions

In this paper, we presented one possible way of bridging the gap between semiotics, a general science of signs, and computational semiotics, the trial in building computational systems that would be performing some semiotic processes.

A lot of questions remain unsolved. For example, ... , is our model for the sign a dyadic or a triadic model ? Some people would say that we are building a dyadic model for a sign, but, there is some kind of “mediation” mechanisms, mainly due to the focus of attention mechanism and the possible influence that some knowledge units may have over the processing of other knowledge units (which we call in this case catalytic knowledge units).

We still need to do further reflections in order to have a better position on this issue. We need to remember that our model is not a pure analytical model anymore, but a model of synthesis. We will need to find what exactly firstness, secondness and thirdness does mean in this case, in order to build a good judgment of the situation. This is something we plan to write about in the future

What should be remembered and even stressed here, is that this is not the final word regarding Computational Semiotics. It is only a first exercise in order to get insights to the problem of semiotic synthesis. A very preliminary one. What makes us invest our efforts on it is that, having a computational implementation of such a model, this computational implementation, up to some point, makes us feel that it is worth the value of working on it. The results we obtained were very satisfactory.

For the future, what we expect is to collect comments from the scientific community in order to improve our model. For that sake, we are prepared inclusively to rewrite all the background ideas posed in this paper, if necessary. Our conviction is that semiotics is a very powerful science and we must use it in order to get insights for the creation of a new generation of intelligent systems. We don't have the presumption to say that our model is a model for what happens within a human mind, for example. We only want to get insights in order to build systems that may behave, up to some sense, as we humans do, regarding intelligent behavior.

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