# Towards Meaning Processes in Computers from Peircean Semiotics

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## ABSTRACT

In this work, we propose a computational approach to the triadic model of semiosis (meaning processes), as stated by Charles Sanders Peirce. His model of semiosis represents a key element in the construction of the next generation of intelligent artifacts able to overcome current AI limitations, such as the *symbol grounding* problem. The contributions of the Peircean semiotics to the construction of intelligent systems were not yet systematically explored. In fact, most approaches in the literature adopt a naïve definition of semiosis, which usually plays a secondary role in the study. Our research, on the other hand, strives for a strong theoretical foundation for meaning processes, as well as its realization within digital computers. We investigate theoretical constraints about the feasibility of simulated semiosis. These constraints, which are basic requirements for the simulation of semiosis, refer to the synthesis of irreducible triadic relations (Sign – Object – Interpretant). We examine the internal organization of the triad, that is, the relative position of its elements and how they relate to each other by determinative relations. We also suggest a multi-level (micro and macro-semiosis) computational approach based on self-organization principles. In this context, relations of determination are described as emergent properties of the system.

## 1   INTRODUCTION

Computational-based methodologies have been used to design virtual experimental protocols, where it is possible to simulate the predictions derived from theoretical models (Bedau 1998, Parisi 2001), in particular those describing semiotic processes in artificial systems. Computer simulations can be used to study different levels of the organization of semiotic processes (Cangelosi & Turner 2002, Parisi & Cangelosi 2002, Perfors 2002). These levels include the simulation of syntactic structures (Batali 1998, Batali 1998, Kirby 1999), morpho-syntactic compositionality (Ellefson 2002), lexicalization phenomena (Hurford 1991, Steels 1999, Cangelosi & Parisi 1998, Steels et al. 2002), symbolic competence (Cangelosi 2001), communication (Hutchins & Hazlehurst 1995, Steels

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1997, Steels & Kaplan 1999, Kvasnicka & Pospichal 1999), and meaning creation in communication (MacLennan 2001, Smith, in press).

Here we propose a computational model of C.S. Peirce's triadic notion of meaning processes (or semiosis). In order to synthesize artificial systems able to perform some sort of semiosis, we

1. introduce some principles of Peirce's philosophy of sign,

2. define the major theoretical constraints required in semiosic simulation,

3. specify a computational strategy to implement semiosis according to the afore-mentioned constraints, and

4. propose a system implementation in which one can observe emergence of semiotic processes.

## 2    PRINCIPLES OF PEIRCEAN SEMIOSIS

The Peircean list of logical/phenomenological categories (Firstness, Secondness, Third-ness) constitutes an exhaustive system of hierarchically organized classes of relations (monadic, dyadic, triadic) (Houser 1997:14; Brunning 1997). This system is the formal foundation of his architectonic philosophy (Parker 1998:60) and of his model of semiosis (action of sign) (Murphey 1993: 303-306, Kent 1997:448). Peirce defined semiosis as an irreducible triadic relation (EP2:171) between Sign-Object-Interpretant (see Burch 1991; Brunning 1997; Peirce SS 43, CP 1.363, 8.331, CP 7.537) . According to Peirce, any description of semiosis involves, in a non-intuitive way (Deacon 1998:69-70), a relation constituted by three irreducibly connected terms (S-O-I), which are its minimal constitutive elements (MS318:81, CP 2.242, CP 2.274).

"A Sign is anything which is related to a Second thing, its Object, in respect to a Quality, in such a way as to bring a Third thing, its Interpretant, into relation to the same Object, and that in such a way as to bring a Fourth into relation to that Object in the same form, ad infinitum" (CP 2.92).

For the purpose of this work, we must consider an important sub-division on the nature of the object:

"We must distinguish between the Immediate Object, -- i.e. the Object as represented in the sign, -- and the Real (no, because perhaps the Object is altogether fictive, I must choose a different term, therefore), say rather the Dynamical Object, which, from the nature of things, the Sign cannot express, which it can only indicate and leave the interpreter to find out by collateral experience" (CP 8.314, see 8.343).

In the next section, we investigate these definitions and identify the major theoretical constraints required to simulate semiosis.

# 3   PEIRCEAN SEMIOTICS CONSTRAINTS

We divide the theoretical constraints into two sections. The first investigates the relative positions and the second the relations of determination between terms.

## 3.1   RELATIVE POSITIONS OF S-O-I

Let a chain of triads be $T = \{..., t_{i-1}, t_i, t_{i+1}, ...\}$, where $t_i = (a_i, b_i, c_i)$ and $i \in \mathbf{N}$. Then the following conditions must hold:
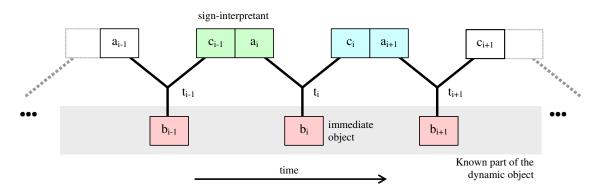


**Figure 1:** Model of relative positions of S-O-I

$$\forall i: a_i = c_{i-1} \tag{3.1}$$

$$\exists d \ \forall i: \text{ImmediateObject}(b_i, d) \tag{3.2}$$

where the logic predicate $\text{ImmediateObject}(b_i, d)$ denotes that $b_i$ is an immediate object of a dynamic object d. It is of paramount importance to notice that the equality expressed in Equation 3.1 means that, in fact, $c_{i-1}$ and $a_i$ are just aliases for the same thing – $c_{i-1}$ and $a_i$ are roles played by this "thing" within triads $t_{i-1}$ and $t_i$ respectively.

The constraints represented by equations 3.1 and 3.2 mean that, given any triad $t_i = (S_i, O_i, I_i)$ in a chain T:

- its first term ($S_i$) must be equal to the third term of the preceding triad ($I_{i-1}$)

- there exists at least one dynamic object (whole gray area at the bottom in Figure 1) such that all second terms ($O_i$) are immediate objects of it,

- its third term ($I_i$) must be equal to the first term of the subsequent triad ($S_{i+1}$), and a triad $t_i = (S_i, O_i, I_i)$ can only be defined as such in the context of a chain of triads $T = \{..., t_{i-1}, t_i, t_{i+1}, ...\}$.

First terms are Signs, Second terms ($O_i$) are Objects, and Third terms are Interpretants.

## 3.2   RELATIONS OF DETERMINATION

Determination provides the way the triad elements are arranged to form a sign. According to Peirce

> "The sign is determined by the object relatively to the interpretant, and determines the interpretant in reference to the object in such a way as to cause the interpretant to be determined by the object through the mediation of the sign" (MS 318:81).

These determinations can be rewritten as:

1. O determines S relatively to I

2. S determines I relatively to O

According to Ransdell (1983:23), determination encompasses a both *causal* and *logical* idea. In this context, how do these causal and logical modes operate? What does a triadic relation expressed as '*X determines Y relatively to Z*' means? A computational approach to this problem will be provided in the following sections.


# 4   PRELIMINARY APPROACH TO SEMIOSIS

Consider the assumption that semiosis is a dynamical process that happens *in time*. Hence, each new triad is appended at the end of the chain of triads, according the constraints given in Section 3, that is:

$$\ldots \rightarrow (S_{i-1}\, O_{i-1}\, I_{i-1}) \rightarrow (S_i\, O_i\, I_i) \rightarrow (S_{i+1}\, O_{i+1}\, I_{i+1}) \rightarrow \ldots$$

We propose that semiosis operates at two distinct levels that, together, may provide a more comprehensible treatment to synthetic approaches:

At the higher level, here designated by *macro-semiosis*, chains of triads are created and evolved. Each chain possesses some crucial properties, such as being potentially infinite (unlimited semiosis) and always referring to the same object. In the work of Peirce and many of his followers, this is the closest we get to the understanding of semiosis as a dynamic process happening in time. On the other hand, from a computational viewpoint, this resolution *per se* does not provide a suitable knowledge on how to effectively realize the evolution of chains in a computer.

As a result of the aforementioned arguments, there is a motivation for the proposal of a lower level, here designated by *micro-semiosis*, that focuses on how relations of determination are computationally created inside the triad itself (see Figure 2).

Micro-semiosis refers to each simulation step in the process of signification, that is, the realization of the triadic relation within triads. An important consequence is that S-O-I triadic relations are not necessarily created in atomic steps. This view is suitable to the implementation of computational strategies, as most techniques (neural networks, genetic algorithms, etc.) are based on iterative algorithms.
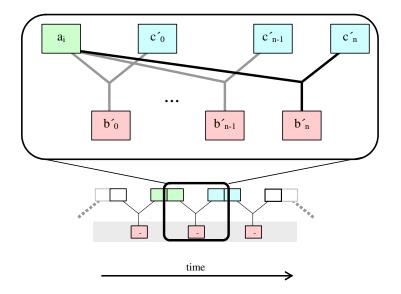
**Figure 2:** Macro-semiosis (bottom) and micro-semiosis (top)

A relation of determination may be, in this sense, gradually refined until it reaches a minimum trade-off between the computational resources required and the conformity with theoretical constraints.

# 5   PROPOSAL FOR AN ALGORITHM

This section presents a computational strategy to implement simulated semiosis within digital computers. The iterative algorithm proposed here relies on the notion of macro and micro-semiosis stated earlier. The level of detail provides a general framework in which computational techniques, such as neural networks, genetic algorithms, classifier systems, and so on, can be applied to effectively simulate semiosis.

## 5.1   GENERAL DEFINITIONS

For the purpose of the present development, an *iterative process* can be described as an ordered sequence of operations $\{A_1, A_2, ..., A_i, ..., A_n\}$. Thus, an operation $A_i$ can only be performed after $A_{i-1}$, and $A_{i-2}$ only after $A_{i-3}$, and so on.

Other important definitions and requirements are given. There exist *driving constraints*: (i) O is the primary constraining agency of semiosis, and (ii) S is the primary agency of semiosis. There are three modalities of relation between a first (Sign) and a second (Object): (i) intrinsic quality of S (first term dependent), (ii) S-O relational quality (first-second relation dependent), and (iii) imputed quality by I to S-O (third term dependent).

**Definition 5.1**: A *potential sign*, in the course of an iterative process, is something that may be the sign of an object (*stand for*) to an interpretant.

**Definition 5.2**: A *potential object*, in the course of an iterative process, is something that may be the Object of a Sign to an interpretant.

**Definition 5.3**: A *potential interpretant*, in the course of an iterative process, is something that may be the interpretant of a Sign (*stand to*).

A potential sign becomes a sign only when submitted to a mediative relation of determination between Object and Interpretant. Being determined by the Object, the Sign is
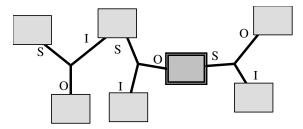


**Figure 3:** Semiotic nature of elements, in which everything may be interpreted as a sign.

constrained by it. This means that the Sign can only assume its role as a Sign if attested as such by the Object. Determining the interpretant, the Sign constrains it.

## 5.2   ALGORITHM

Consider the statements: (i) O determines S relatively to I, (ii) S determines I relatively to O. Arbitrarily, let's start by the first statement. From a computational point of view, the first question is: which one of the terms comes first in time? If we read determination as a causal process we are tempted to state that $S = f(O, I)$. One of the problems with this view is that O is not available before S, and I is not available before $O^{32}$. The fact that O determines S relatively to I means that S assumes its condition because of O (O causes S) and I, but does not mean that either O or I are available. This affirmation may lead us to a sort of dead-end because it provides no starting point. However, if determination is seen as a logical-causal constraint there may be alternative ways to perform this process.

Assume that S´, which is available at time t, is a potential sign. S´ has an *interpretive potential*, that is, the faculty of being potentially interpretable (I) as a Sign of something (an Object). Then, we need to find an Object O´ and an Interpretant I´ that assumes a triadic relation with S´. If the theoretical constraints (Section 3) are satisfied, we can then say that they form a sign (at a time t´ > t).

We propose an algorithm to perform micro-semiosis. It presupposes the notion of environment and agent. The synthetic environment represents the reality that is forced upon the agent's sensors. The environment is infinitely complex (from the viewpoint of the agents[33]). Agents, which are immersed in the environment, are able to perceive and act on the environment.

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[32] From Figure 1, we can see that $S_i$ ($a_i$ in the i-th triad) is obtained from $I_{i-1}$ ($c_{i-1}$ in the preceding triad in the same chain).

[33] This means that the agent is able to perceive only part of its "reality".

The steps of the algorithm are as follows:

1. *Choose* a collection of potential signs PS = {S´$_i$};

2. *Choose* one potential sign S´ from this collection;

3. *Propose* a potential object O´ and a potential interpretant I´, such that there exists a *relation* in one of the three *possible modes* (see above for intrinsic, relational and imputed qualities). Then, we say that O´ determines S´ relatively to I´.

Comments about the algorithm:

- The collection of potential signs may encompass virtually everything available in the system, as anything can be seen as a sign (see Figure 3);

- The selection of a potential sign may sound somewhat arbitrary, as one may suppose that it is just a matter of time to find a suitable relation with a chosen O. However, it is quite reasonable to propose some sort of *selection mechanism* to increase the effectiveness;

- Step 3 is the most difficult of all, because it requires some sort of emergent behavior. Emergence, by its own, cannot be achieved atomically, that is, it demands many separated steps that are performed sequentially in time (an iterative process). In this case, many candidate pairs are proposed and selected. Possibly, there must be some sort of fitness measure to guide this process.

The potential objects are things that are available in the environment, through the mechanisms of perception. They are things that exist; they are things that turn into Objects from Signs.

In order to implement this algorithm one must first define some sort of cognitive architecture for the agent, in which sensors and effectors are specified. Many details were left out. The goal of this proposal is to state very basic steps to perform simulated semiosis.

## 6   CONCLUSIONS

Currently, there is no tractable computational model based on a strict definition of Peirce's semiosis. A sizeable amount of other research, however, based on other notions of semiosis, has been proposed to simulate sign processes in computers (Gudwin 2001, Guerrero et al. 1999, Meystel 1996, Pospelov 1991).

This research, which is a work in progress, strives for a solid understanding on how to simulate Peircean semiosis (meaning processes) within digital computers. We have shown in this article a brief overview of the Peircean semiotics, and pointed out two fundamental constraints that are required to simulate semiosis, namely, the relative position of triad elements and the relations of determination between them. Based on these constraints, we proposed a general algorithm to accomplish artificial semiosis. This algo-

rithm derives from the notion of macro and micro-semiosis. This proposal still lacks many details, but sketches a general framework to design experimental semiotic systems.

Further developments will include a more detailed algorithm and an implementation of artificial semiosis in a computer.

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