CHAPTER SEVEN

Peirce And The Engineering Of Intelligent Systems

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In Computer Science and Computer Engineering, Intelligent Systems are a designation for a class of artificial technical systems where their creators specifically intend the system to reproduce the same kind of behavior that an intelligent being would be performing, if submitted to the same conditions and sensing data. Even though the field of intelligent systems is quite developed, with many specialized journals, scientific societies and conferences all around the world, there is no such a thing as a Theory of Intelligent Systems, or a clear definition on which conditions a system might be declared intelligent or not. Instead of that, the field is fragmented into a set of more or less independent methods and techniques (e.g. fuzzy systems, neural networks, evolutionary computation, swarm intelligence, rule-based systems, mathematical logic, heuristic search, etc., etc.) which usually are considered as "distinctive marks" of an intelligent system, but usually does not give us more information on why they should be unified as a field of investigation.

One of the reasons for this theoretical "gap" is the lack for a proper definition of intelligence, or at least a common understanding on a wide scope meaning for this word in the many contexts where it might be applied.

The American philosopher Charles Sanders Peirce (1839-1914), considered to be one of the most original thinkers of his time, father of American Pragmatism and Semiotics, touches the issue of intelligence and intelligent action in many of his writings, up to the point of identifying intelligence with the property which makes a sign to work like a sign, through the process of "Semiosis".

Our main goal, with this work, is to defend the idea that Peirce's Semiotics could be the substrate background on which a whole Theory of Intelligent Systems might be developed in the future. To elaborate such argument, though, I will have to first introduce some of Peirce's concepts and ideas, and further make a correlation of these ideas on the basis of General Systems Theory.

I will have to propose a slight detour to talk about Perception, Cognition and Behavior, showing up how these are intertwined in the construction of an intelligent system, and how Peirce's concepts can be applied to model these phenomena, and at the end, I hope to be able to convince the reader that not only Peirce's theory can be used as a unification grounding theory to generalize and abstract current intelligent systems' techniques and methods, but also could open a whole avenue of research for enriching the field with new perspectives.

To understand Peirce, though, is not an easy task. Peirce is the kind of philosopher which builds his theories as meta-theories, or, in other words, his theories are all derived from a core of concepts which, from a unique perspective, describe the grounding of the universe, and these core concepts are then applied recursively in many substrates and layers, deriving new concepts and ideas in many different domains and subfields.

Theory of Categories

One of these core concepts is his "Theory of Categories". Peirce's categories are "philosophical arrangements, a table of conceptions drawn from the logical analysis of thought and regarded as applicable to being" (CP 1.300)[1]. Peirce developed his categories based on previous works from Aristotle and Kant. Aristotle defined a list of 10 categories of being, based on the kinds of words used to refer to the world: substances, quantities, qualities, relations, locations, times, being-in-a-position, having-a-state, action and affection. Kant defined a list of 12 categories of being, based on the kinds of judgments about the world, divided into 4 modalities - categories of quantity: unity, plurality, totality - categories of quality: reality, negation, limitation - categories of relation: inherence and subsistence (substance and accident), causality and dependence (cause and effect) and community (reciprocity between agent and patient). Peirce defines a list of 3 categories, based on the **kinds of relation** able to happen in the

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1 It is common among Peirce scholars to represent citations to the work of Peirce using a mnemonic code given by letters and numbers. In this case CP implies the *Collected Papers of Charles Sanders Peirce* (Peirce, 1931-1958), and 1.300 implies volume 1, paragraph 300. Other encodings can be found at <http://en.wikipedia.org/wiki/Charles_Sanders_Peirce_bibliography>.

world: firstness, secondness and thirdness. They were presented originally in (Peirce 1867) and further worked and enhanced all through his life. Contrary to Aristotle's and Kant's categories, Peirce's categories are meta-categories. In other words, they might be recursively applied in order to generate new kinds of categories. Peirce's categories are the foundation of most of Peirce's theories. They are highly abstracted categories.

Firstness is the mode of being of that which is such as it is, positively and without reference to anything else (CP 8.328; 1.295). The idea of First is predominant in the ideas of freshness, life, freedom (CP 1.302), novelty, creation, originality, potentiality, randomness.

Secondness is the mode of being of that which is such as it is, with respect to a second but regardless of any third (CP 8.328; 1.296). The idea of second is predominant in the ideas of causation and of statical force (CP 1.325), comparison, opposition, polarity, differentiation, existence (opposition to everything else).

Thirdness is the mode of being of that which is such as it is, in bringing a first and second into relation to each other (CP 8.328; 1.297). The idea of third is predominant in the ideas of generality, infinity, continuity, diffusion, growth, intelligence (CP 1.340), meaning, mediation and representation.

Signs and Representation

The theory of categories is used by Peirce to describe the concept of a sign, or representation. During his life, Peirce presented many different definitions of sign (Marty & Lang, 1997). According to one of these definitions:

A **Sign**, or Representamen, is a First which stands in such a genuine triadic relation to a Second, called its **Object**, as to be capable of determining a Third, called its **Interpretant**, to assume the same triadic relation to its Object in which it stand itself to the same Object (CP 2.274).

This sign definition, as presented here, is an abstract technical definition, which was slightly changed during Peirce's life (Short, 2006). To improve understanding of the notion of a sign, particularly in the case of an intelligent system, we will make use of the following scenario, which can be very pedagogic in presenting the same idea, from a more practical context. Let us consider an environment, populated by a certain number of objects and agents. An agent (Luck & D'Inverno 2001) is our prototype of an intelligent system. We suppose that an **object** is able to cause an effect in the agent, in some sort of way. In the absence of the object, for any reason, we suppose that something else, which we call a **sign**, is able to cause the same effect in the agent. The effect caused in the agent is called its **interpretant**. According to Peirce's early theory of signs, this interpretant might necessarily also be a sign. Peirce's late theory of sign (Short 2006) modified that constraint. According to the late theory, the effect of the sign might be the creation of a feeling, an action or another sign, possibly more evolved (CP 5.475). In the case a sign's effect is a feeling, it is called an **emotional interpretant**. In the case a sign's effect is an action, it is called an **energetic interpretant**. And finally, in the case the effect of the sign is the creation of another sign, in the interpreter's mind, it is called a **logical interpretant**.

Another important distinction made by Peirce refers to the many kinds of objects and interpretants a sign might have. According to him "... it remains to point out that there are usually two objects, and more than two interpretants. Namely, we have to distinguish the **immediate object**, which is the object as the sign itself represents it, and whose being is thus dependent upon the representation of it in the Sign, from the **dynamical object**, which is the reality which by some means contrives to determine the sign to its representation. In regard to the interpretant we have equally to distinguish, in the first place, the **immediate interpretant**, which is the interpretant as it is revealed in the right understanding of the sign itself, and is ordinarily called the meaning of the sign; while in the second place, we have to take note of the **dynamical interpretant** which is the actual effect which the sign, as a sign, really determines. Finally there is what I provisionally term the **final interpretant**, which refers to the manner in which the sign tends to represent itself to be related to its object" (CP 4.536).

Icons, Indexes and Symbols

An important point here, specifically in the case of intelligent systems, is how a sign is able to perform its role as sign, or in other words, how a sign is able to cause an effect in the agent. Not just any effect, but the same effect that its object might cause. This "power" of the sign comes from the possible relation which it might have to its object. Depending on this relation being a firstness, a secondness or a thirdness, this will result in different kinds of signs. If a sign maintains a similarity or analogy to its object or, if the sign have in itself the same properties or qualities as its object, this is where this power comes from. In this case, it is called an **icon**. The relation binding the sign to its object, in this case, is in the sign itself, so it is a firstness. If the sign, for some reason, forces the attention to a particular object intended without describing it, like e.g. a demonstrative or relative pronoun, or if there is a direct physical connection between the sign and the object which can be used to draw attention to it, it is called an **index**. In this case, the relation binding the sign to its object is in existence. Then this relation can be tracked down in existence in order to reach the object (secondness). Finally, if the sign is related to its object by means of an association of ideas or habitual connection between the sign and the character signified, it is called a **symbol** (CP 1.369). In this case, the connection between the sign and object depends on a third thing, besides the sign itself and the object itself, which is an habit connecting sign and object. In this case, the relation between sign and object is a thirdness.

Peirce and General Systems Theory

Now, to investigate the possible connection between Peirce's theory of signs and intelligent systems, we will perform an application of Peirce's concepts to General Systems Theory (Bertalanffy 1950; 1972). According to General Systems Theory, a system is defined as a set of interacting elements. Each element might have a set of properties which might be fixed or vary through time. These properties might be observable (which means they are measurable) or non-observable (which means that despite having some value, this value cannot be measured by a physical device). Properties might assume different values through time. According to the three Peircean categories, these values might have three possible ways of variating.

- Random Determination
- Interactive Causal Determination
- Finalistic Determination

In the first case of determination, firstness is the driving force commanding the property value's variation. The new property value do not depend in anything else, being completely random. In the second case, secondness is the driving force commanding the property value's variation. The new property value is a deterministic function depending completely on the values of other property values in the system, or in the variation of other property values in the system. This is the standard determination case in pure mechanistic systems. The third case needs a more proper explanation. The notion of *final cause* defined by Aristotle, as the tendency to a final state, despite its common use in Biology to refer to some kinds of organism's behavior, was during a long time criticized as being a non-scientific mysticism introduced by Aristotle's religious ideas (Mayr, 1992). Nevertheless, people working with Cybernetics (Rosenblueth et.al., 1943; Christensen 1996) showed that teleological behavior is just a collateral effect caused by a system feedback in its interactions. In this phenomenon, some property value acts as a reference set point, driving the property value updates of other properties, such that successive updates in these values will lead this property to assume the same value prescribed by the reference property. Nowadays, this is a common knowledge widely used by control engineers to set up control systems. Nevertheless, this is a curious case of the manifestation of thirdness in general systems engineering. These special property values actuate as thirds, mediating the determination of other property values through time up to a final predetermined state. As a corollary of this, any kind of purposive behavior can be possibly explained by the presence of feedback and the existence of specific properties which will assume the role of reference set points for the finalistic determination.

The Semiotic Role of Sensors

Another important analysis to be performed in the sequence is related to the semiotic role of sensors in intelligent systems. Usually, in an intelligent system, we consider the system (agent) to perceive its environment, identifying objects and situations happening at the environment.

The problem is that the agent doesn't have a direct access to the objects and situations happening in the environment. The only point of contact between the agent and the environment is through their sensors and actuators. This means that objects and situations in the environment cannot directly affect an agent. An agent can only be affected by means of signs. And particularly, these signs are conveyed by means of sensors.

What are sensors doing? Sensors are devices which transduce some physical property into another physical property, such that a topological relation is established among these two physical properties, in the sense that every time the first physical property assumes a given value, the second physical property will assume a corresponding physical value which is specific and unique. This is what happens, e.g. in a thermometer. Now, here comes a tricky part to our argumentation. Usually, a sensor as a thermometer is considered to be an index, because there is a physical correlation between the property being measured and some property in the sensor. Peirce himself uses the example of a thermometer to explain how an index works (CP 5.473). This might be the case, if the process of interpretation uses the correlation between properties to draw our attention to its correlated property. This happens, e.g., when we look at a weathercock direction and this draws our attention to the direction of the wind. But now let's imagine a different situation. Our agent does not know what is a temperature. The only way of knowing the temperature is through its sensor. In this particular case, the agent cannot have its attention drawn to something else, because it does not have access to something else. Thus, in this particular case, a sensor cannot work like an index. So, how does it works? Let's try to explain. There is a physical property in the environment, which is temperature, and there is a physical property in the thermometer, which is the extension of the mercury column. When the temperature is, say, 39 degrees, the mercury column will have an extension which is determined and unique for the case of a temperature of 39 degrees. For an electric thermometer, the voltage of the sensor will be a definite and unique voltage for the case of a temperature of 39 degrees. If I couple this electric thermometer to a 32 bits analog-to-digital (AD) converter, there might be a computer memory set of flip-flops which will be holding the numeric encoding of a 32 bit number which will be definite and unique for the case of a temperature of 39 degrees. What do all these (the environment temperature, the mercury thermometer, the electric thermometer, and the electric thermometer with an AD converter) have in common? They are all in a relation of analogy to each other. So, according to Peirce's

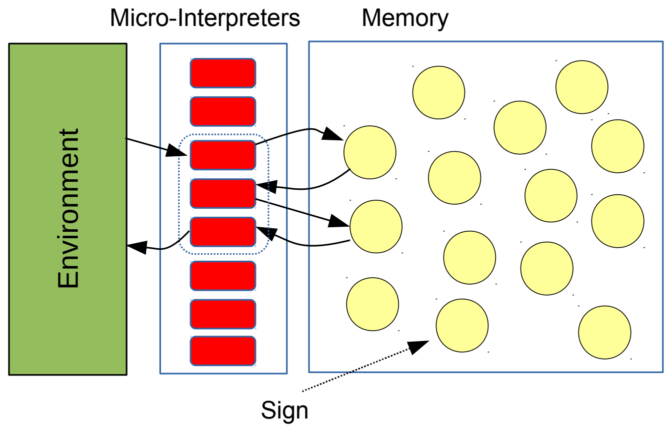

Figure 1: Semiotic Model of an Intelligent System

definition of an icon, in this particular case, when an agent has only the sensor as point of contact with the environment (and probably just in this particular case), a sensor can be considered an icon. According to Peirce, icons can be of three types: images, diagrams and metaphors (CP 2.277). **Images** are icons which present in themselves the same properties as their objects. **Diagrams** are icons which in their parts present the same state of affairs as the parts of their objects. And **metaphors** are icons which hold in themselves another kind of parallelism, e.g. some sort of analogy to their objects. So, in a Peircean sense, sensors, are **iconic metaphors**, being able to represent their objects, because they have properties which are in a relation of analogy to the properties of the objects they represent[2].

A Semiotic Model of Intelligent Systems

With the proper analysis of the semiotic role of sensors, we can now proceed to develop a semiotic model of an intelligent system. A diagram showing the model can be seen in figure 1. In this model, an intelligent system, or an agent, is modeled as a set of micro-interpreters and a memory, where signs are created and stored. Two specific kinds of micro-interpreters are sensors and actuators. Let us explain this model in more detail.

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2 It is important to notice that the above interpretation is very controversial and absolutely non-standard among semioticians.

We said in last section that sensors could be considered as signs, being classified as icons, or iconic metaphors. But in fact sensors are more than simply signs. Besides their sign aspect, they are also **micro-interpreters**. In this particular case, we will split a sensor (and also an actuator) in its micro-interpreter and sign aspects, becoming a sensory (or motor) micro-interpreter and a sensory (or motor) sign. The micro-interpreter part of them will be the physical devices, and the sign-part of them will be holding the necessary information to represent something. We will explain this better in a section ahead.

Our main hypothesis is that it is possible to reduce any kind of intelligent system to this meta-model of a set of micro-interpreters and a memory where different kinds of signs can be stored. The notion of a **micro-interpreter** is defined here as a component of the intelligent system which is able, in the presence of a sign, to generate an effect in the intelligent system. The prefix **micro** in micro-interpreter is due to the fact of considering it as an element of a micro-level in a hierarchical system (Salthe 1985). The sign might be in the environment or internally within the memory. The effect generated by the micro-interpreter could be the generation of a new sign in the system's memory, or the generation of an action in the environment, through actuators. In this sense, a sensor might be a micro-interpreter, and also actuators might be considered micro-interpreters. Micro interpreters might be hardware devices, like sensors and actuators, or software processes in a computational system. In order to perform its role as a micro-interpreter, software processes might use iconic strategies (pattern-matching, analogy discovery, etc.), indexical strategies (focus-of-attention, attention attractors) or symbolic strategies (internal habits representations) in order to interpret icons, indexes and symbols.

Micro-interpreters can perform their role using just the sign as input to their activity, or use accessory signs, which might be necessary in order to fulfill their behavior. Using this meta-model of signs and micro-interpreters, we can represent all kinds of known intelligent systems: fuzzy systems, neural networks, evolutionary computation, swarm intelligence, rule-based systems, search in graphs, Bayesian networks, etc. (see Gudwin, 1997).

Particularly, we might use this model to build different sorts of Cognitive Architectures (Sun 2004), splitting the set of micro-interpreters into subsets dedicated to integrate particular cognitive functions, and splitting the memory in different kinds of memory, as can be seen in figure 2.

Sensory Input micro-interpreters are usually sensor devices of many possible different kinds. In human beings these micro-interpreters might be eyes (visual sensors), ears (auditory sensors), nose (olfactory sensors), tongue (gustatory sensors), skin (tactile sensors). In artificial intelligent systems, they can be any kinds of sensors. Motor Output micro-interpreters are usually also hardware devices, responsible for the generation of action in the environment and also internally in the system body. In human beings they are mostly muscles responsible for different kinds of movements. In artificial intelligent systems, they can be any kind of actuator responsible to drive some sort of movement in the intelligent system (internal or external).

The other groups of micro-interpreters are usually instances of different possible kinds of processes able to perform as needed in order to fulfill their role. In human beings they might be groups of neurons in the brain, and in computational artificial systems they might be software processes, or software objects. We might have micro-interpreter groups for perception, attention, emotions, learning, language, consciousness, imagination and planning and behavior generation. This division is rather arbitrary, and not necessarily all intelligent systems might implement all those cognitive capabilities. More complex intelligent systems might have other cognitive functions (e.g. meta-cognition, etc.), and

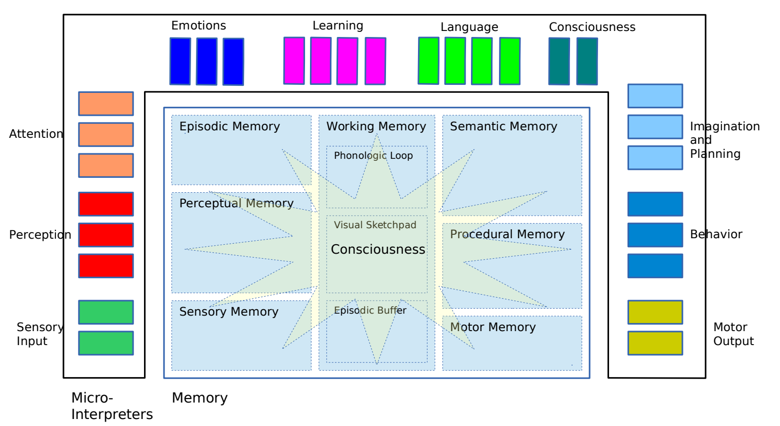

Figure 2: A Generic Semiotic Cognitive Architecture

simpler intelligent systems might have just some of them (e.g. sensory input, perception, behavior and motor output). In this paper, besides sensory input and motor output which are hard-implemented in physical devices, we will focus only on perception and behavior generation processes. The semiotic engineering of other cognitive functions will be left for future publications.

Perception and Software Objects

According to Peirce, "The elements of every concept enter into logical thought at the gate of perception and make their exit at the gate of purposive action; and whatever cannot show its passports at both those two gates is to be arrested as unauthorized by reason" (CP 5.212). But besides that, "all thought is in signs" (CP 5.253). So, the elements of the perceptual experience should be also signs or sign-related. Peirce developed a special theory to deal with perception (Luisi 2006; Rosenthal 2006; Santaella 2012). In this theory, the perceptual experience is both direct (secondness) and interpretive (thirdness). It is “direct” in the sense that we perceive real things without first perceiving things whose existence depends upon the act of perceiving them. And it is “interpretive” in the sense that perception is in some way, or at some level, determined or influenced by one’s store of concepts and beliefs (Wilson, 2012). The direct aspect of the perceptual experience is called by Peirce a **percept**. And the interpretive aspect of the perceptual experience is called a **perceptual judgment**. But then Peirce proposes to consider the percept as it is immediately interpreted in the perceptual judgment, under the name of the **percipuum** (CP 7.643). The exact relation among percept, percipuum and perceptual judgment is a little controversial among Peirce scholars (Rosenthal 1969; Bergman 2007). Santaella (2012) proposes that in a perceptual experience, the percept performs the role of a dynamical object, the percipuum performs the role of the immediate object and the perceptual judgment performs the role of the sign.

Peirce also differentiates past perceptual experiences, which he calls **ponecipuum**, from anticipations of the near future, which he calls **antecipuum**. Both these experiences are also split into two parts, so it is possible to talk about a **ponecept**, as a percept in the past, and an **antecept**, as an anticipation of a percept in the near future (CP 7.648).

According to Peirce, "every percept is the product of mental processes, or at all events of processes for all intents and purposes mental, except that we are not directly aware of them; and these are processes of no little complexity" (CP 7.624). More than this, "two different kinds of elements go to compose any percept. In the first place, there are the qualities of feeling or sensation, each of which is something positive and sui generis ... it is convenient to call these the elements of 'Firstness' ... these elements of Firstness are perceived to be connected in definite ways" (CP 7.625). And finally, "we know nothing about the percept otherwise than by testimony of the perceptual judgment, excepting that we feel the blow of it, the reaction of it against us, and we see the contents of it arranged into an **object**, in its totality" (CP 7.643).

It is remarkable the correlation that the notion of a percept/perceptual judgment has in common with the notion of an **object**, in computational processes and object-oriented programming (Smith, 1998). Objects (or **s-objects** -- *software objects*, to avoid a possible confusion with the object of a sign) are computational representations for objects in the real world. So, if an object in the real world is a percept, the s-object is its perceptual judgment. The notion of an **s-object** comes from a variety of philosophical assumptions since Aristotle with his **substance theory,** passing through Hume, with his **bundle theory**, up to Gibson (1986), with his notion of **affordances**. According to this notion, an s-object is a collection of other objects, called its **parts**, plus a collection (or bundle) of **properties**, plus a collection of **affordances**. Affordances are possible actions which can be performed on the object. According to Gibson (1986), there might be some kinds of objects which can be defined strictly based on their affordances, e.g. a chair is anything which can be sat on.

In intelligent systems, the role of perception can be understood as a sensory data-based process through which the system is able to discover and recognize s-objects in its environment. From a semiotic perspective, s-objects are (just like sensors) iconic metaphors of the environment objects they represent. Following the standard strategy for interpreting icons, there are many computational techniques like pattern-matching and statistical correlation which can be used to perform this role.

According to our meta-model of an intelligent system, perception can be instantiated in micro-interpreters which use sensory data stored as s-objects, and translate them into other s-objects representing the discovery of objects in the environment. Besides that, these s-objects might be performing some sort of change in its attributes through time, giving rise to the description of **scenes** and **sequences of scenes** also through time. The storage of an appropriate representation for these sequences of scenes will constitute what cognitive psychologists call an **episodic memory**.

The discovery of s-objects, scenes and sequences of scenes constitute what we might call a world model for the intelligent system, which might be further used for the system's behavior generation (Meystel & Albus 2002).

Behavior Generation and Kinds of Behavior

One of the key notions in an agent (intelligent system) is the notion of behavior generation. According to our semiotic meta-model, the system behavior shall be constructed by means of micro-interpreters making interpretations using signs previously constructed by perception as their background. This behavior might be constructed by many different strategies, but following Peirce, we propose that any kind of behavior can be decomposed into three different kinds of behavior:

- Random Behavior (firstness)
- Reactive Behavioral (secondness)
- Goal-based Behavior (thirdness)

These behaviors are somewhat akin to the three different kinds of property determinations we presented in a previous section. Random behavior is a kind of behavior which is randomly chosen among a possible set of behaviors, or stochastic transformations on some previous envisioned behavior. They are an instance of firstness applied to behavior generation. Reactive behaviors are direct consequences of the application of some deterministic algorithm of transformation from perceptual signs, generating some sort of deterministic behavior. They are an instance of secondness applied to behavior generation. Finally, a goal-based behavior, or a purposive behavior, or motivated behavior, is a very special kind of behavior, where there is some goal which is to be achieved, and the behavior is such that it maximizes the chances that such goals are successfully achieved. One interesting remark is that **goal-based behavior** is sometimes called **intelligent**

behavior. Let's for example pay attention to the Meystel & Albus (2002 p. 3) definition of intelligence: "intelligence is the ability of a system to act appropriately in an uncertain environment where an appropriate action is that which increases the probability of success, and success is the achievement of behavioral subgoals that support the system's ultimate goal". This definition is not the only way to define intelligence. And it has some difficulties, which its authors try to fix, but their definition is still inadequate. For example, the notion of **appropriate action** might be questioned, or the notion of **probability of success** also. Nevertheless, it is clear from this definition (and also from many others) that intelligence is connected to goal-based behavior. The problem is how to define what is goal-based behavior. But goal-based behavior is connected to the notion of thirdness. This brings us back to the beginning of this paper, where we started looking for a common ground to define intelligence in intelligent systems. So, if **intelligence** is related to **thirdness**, and thirdness is related to Semiosis, our conclusion is that Semiosis is in the root backgrounds of intelligent systems. We are, in some sense, re-editing Fetzer's Semiotic-System Hypothesis (Fetzer 2001, p. 61), which says that: "a semiotic system has the necessary and sufficient means (or capacity) for general intelligent action".

Peirce and the Future of Intelligent Systems

So, if the reader followed my argumentation up to now, I hope I was able to successfully convince him/her that the notion of Semiosis is a key notion for understanding intelligent systems. Moreover, I prognosticate that the explicit consideration of the many kinds of signs envisioned by Peirce will substantially enrich research in intelligent systems. Most work in intelligent systems today is overly committed to the notion of symbol and symbol processing; I expect that the introduction of other kinds of signs (such as icons and indexes, with all their variations) will enhance and boost research on intelligent systems. This is somewhat acknowledged by the computational intelligence community -- for example, (Bezdek 1993, 1994) proposes a **symbolic to numeric** paradigm shift, yet fails to understand the importance of a strong theoretical background in Peircean semiotics.

When such new similarity measurings and analogies are more widely used to interpret icons, and new focus of attention mechanisms are developed to deal with the notion of indexes, more powerful intelligent systems will appear. More than this, when Peircean Semiotics starts to be used as a background theoretical substrate to explain and justify why intelligent systems are really intelligent, a whole **General Theory of Intelligent Systems** will be able to emerge.

References

Bergman, M. - "Representationism and Presentationism" - Transactions of the Charles S. Peirce Society: A Quarterly Journal in American Philosophy, Volume 43, Number 1, Winter 2007, pp. 53-89.

Bertalanffy L.V - "An Outline of General System Theory" *The British Journal for the Philosophy of Science*, Vol. 1, No. 2 (Aug., 1950), pp. 134-165.

Bertalanffy L.V. "The History and Status of General Systems Theory" - *The Academy of Management Journal*, Vol. 15, No. 4 (Dec., 1972), pp. 407-426.

Bezdek, J. C. (1993). Intelligence: Computational versus artificial. IEEE Transactions on Neural Networks, 4(5), 737.

Bezdek, J. C. (1994) - "What is computational intelligence?" in Computational Intelligence: Imitating Life, J. M. Zurada, R. J. Marks, and C. J. Robinson, Eds. Piscataway, NJ: IEEE Press, 1994, pp. 1-11.

Christensen, W. - "A Complex Systems Theory of Teleology" - *Biology and Philosophy* 11:301-320, 1996.

Fetzer, J.H. (2001) - "Computers and Cognition: Why Minds are not Machines", Studies in Cognitive Systems, vol. 25, Kluwer Academic Publishers.

Gibson, J.J. - "The Ecological Approach To Visual Perception" - Psychology Press (1986).

Gudwin, R.R. and Gomide, F.AC. - "A Computational Semiotics Approach for Soft Computing" - IEEE International Conference on Systems, Man and Cybernetics - SMC'97 - 12-15/October - Orlando, USA, 1997, vol. 4, pp. 3981-3986.

Luck, M. and d'Inverno, M. "A Conceptual Framework for Agent Definition and Development" - *The Computer Journal* (2001) 44 (1): 1-20. <doi: 10.1093/comjnl/44.1.1>.

Luisi, M. - "Percept and perceptual judgment in Peirce's phenomenology" - *COGNITIO-ESTUDOS: Revista Eletrônica de Filosofia, São Paulo, Volume 3, Número 1, p. 065 - 070, TEXTO 07/3.1, janeiro/junho, 2006.*

Marty, R. & Lang, A. - "76 Definitions of The Sign by C. S. Peirce", http://www.cspeirce.com/rsources/76defs/76defs.htm Arisbe Web Site (1997).

Mayr, E. - "The Idea of Teleology" - Journal of the History of Ideas, Vol. 53, No. 1 (Jan. - Mar., 1992), pp. 117-135.

Meystel, A. and Albus, J.S. - "Intelligent Systems: Architecture, Design and Control" - Wiley Series on Intelligent Systems, John Wiley & Sons, Inc., New York, USA.

Peirce, C.S. - "On a New List of Categories." - Proceedings of the American Academy of Arts and Sciences 7 (1867), 287-298.

Peirce, C. S., *Collected Papers of Charles Sanders Peirce*, vols. 1–6, 1931–1935, Charles Hartshorne and Paul Weiss, eds., vols. 7–8, 1958, Arthur W. Burks, ed., Harvard University Press, Cambridge, MA.

Rosenblueth, A.; Wiener, N.; Bigelow, J. - "Behavior, Purpose and Teleology" - *Philosophy of Science*, Vol. 10, No. 1, (Jan., 1943), pp. 18-24.

Rosenthal, S.B. - "Peirce's Theory of the Perceptual Judgment: An Ambiguity" - Journal of the History of Philosophy, Volume 7, Number 3, July 1969, pp. 303-314.

Rosenthal, S. - "Peirce's Pragmatic Account of Perception: Issues and Implications" in Hookway, C. (2006) Companion to Peirce - Cambridge University Press, Chapter 8, pp. 193-213.

Salthe, S.N. (1985). Evolving Hierarchical Systems: Their Structure and Representation. Columbia University Press, New York.

Santaella, L. (2012) - "Percepção: Fenomenologia, Ecologia, Semiótica" - Cengage Learning, São Paulo.

Short, T.L. "The Development of Peirce's Theory of Signs" in Hookway, C. (2006) Companion to Peirce - Cambridge University Press, Chapter 9, pp. 214-240.

Smith, B.C. - "On the Origin of Objects" - Bradford Books, MIT Press (1998).

Sun, R. - "Desiderata for Cognitive Architectures" - Philosophical Psychology, vol. 17, n. 3, September 2004.

Wilson, A. - "The Perception of Generals" - Transactions Of The Charles S. Peirce Society, Vol. 48, No. 2 (2012).