

Eduardo Camargo, Ricardo Gudwin

**FROM SIGNALS TO KNOWLEDGE
AND FROM KNOWLEDGE TO ACTION:
PEIRCEAN SEMIOTICS AND
THE GROUNDING OF COGNITION**

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ABSTRACT

Cognition is meant as the process of acquiring knowledge from the world. This process is supposed to happen within agents, which build such knowledge with the purpose to use it to determine their actions on the world. Following Peircean ideas, we postulate that such knowledge is encoded by means of signs. According to Peirce, signs are anything that can be used to represent anything else. Also, for Peirce, to represent means to be able to generate another sign, called the interpretant of the original sign, which still holds the same power of interpretability, i.e. its power to be transformed into a new sign, holding this same power. This happens through a process called semiosis, the process by which a sign is transformed into an interpretant. This whole process is performed with the aim of subsidizing the agent in deciding its behavior. So, even though the semiosis process has the power to continue infinitely, it usually stops whenever the generated interpretant brings enough information in order for the agent to effectively act in the world. We take signals to be the substratum of signs. Signals are any physical property, which can be measured and captured by the agent, by means of its sensors. This includes any kind of internal memory the agent is able to have access, in order to operate. In this sense, signs can be both in the world (if these signals come from sensors) and within the own agent's mind (if signals come from an internal memory). We understand an agent's mind as the agents' control system. In either case, signals can be abstracted as numbers. Not simply numbers, but numbers coming from specific sensors or specific memories. Using ideas from Peircean philosophy, in this work we postulate a pathway, in which signals, collected by either sensors or memory, can be organized in such a way that they can be effectively used as knowledge, in order for an agent to be able to decide its actions on the world, on the pursuit of its internal motivations. We postulate that agents identify and create a model of the world based on possibilities, existents, and laws, and based on this model, they are able to decide an action that maximizes the chance for the world to gain a shape, which the agents intend for it to be. This theory is postulated particularly for the case of artificial autonomous agents, meant to be constructed by engineering artifacts.

Keywords: Peircean semiotics, knowledge representation, cognitive science.

1. INTRODUCTION

Cognitive science is an interdisciplinary scientific field that connects diverse but related disciplines such as experimental psychology, theoretical linguistics, mathematical logic, and artificial intelligence with the aim of understanding how mind works. In this context, according to Bermudez (2020, pp.15-35), cognition is a form of information processing that allows organisms to interact with their environment to survive. This interaction involves a mind that is responsible for representing the world and developing knowledge about it, providing conditions for the organisms to explore and transform their environment. In short, cognition is meant as the process of acquiring knowledge from the world by an entity equipped with perceptive and actuation devices. Therefore, adopting the approach of *Embodied Situated Cognition*, proposed by Francisco Varela et al. (1991), we consider that perception and action instances are two strongly connected parts of the whole system (see Figure 1), and following some past insights from Gudwin (2014; 2015), we postulate in this work that the study of this kind of connection can be supported by the General Theory of Signs of the American philosopher Charles Sanders Peirce (*1839, +1914).

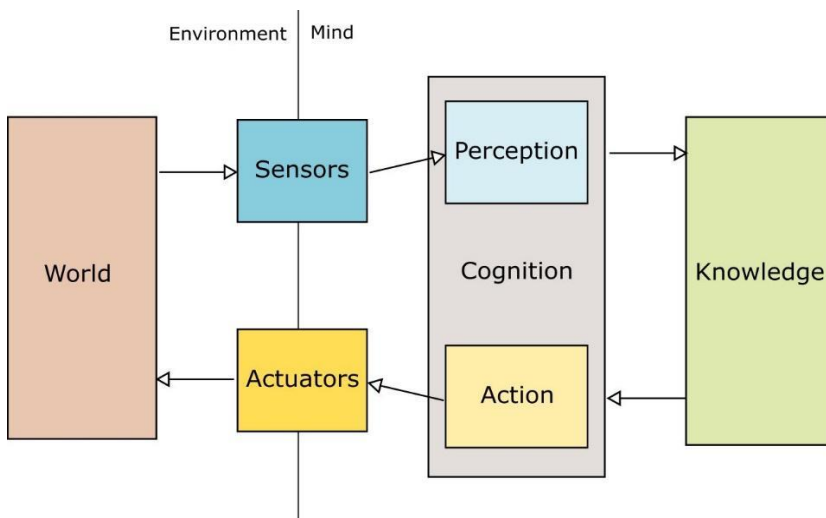


Figure 1: The scope of cognition based on the Embodied Situated Cognition movement

The concept of relations between an organism and its environment, mediated by a mind, takes in account that reality is organized as a system in which each organism affects the surrounding environment and is affected back by the things of the world, including other organisms. However, the presence of a mind must not be considered as an exclusive attribute of bio-

logical entities. As pointed out by Margaret Boden, "... the relation between life and mind is still highly problematic [...]. The common-sense view is that the one (life) is a precondition of the other (mind). But there's no generally accepted way of proving that to be so" (Boden, 2006, p. 1443). In accordance with a broader concept of mind, Peirce claims that thought and mind are not exclusively human attributes and must not be confounded with consciousness. For him, mind is a synonym of representation, and its actuation upon the matter occurs by force of certain laws of final causality. Thus, wherever there are laws, regularities and potentiality there is also rationality, and this should not presuppose consciousness but incorporated knowledge (Santaela, 1994). In Peirce's own words:

"Thought is not necessarily connected with a brain. It appears in the work of bees, of crystals, and throughout the purely physical world; and one can no more deny that it is really there, than that the colors, the shapes, etc., of objects are really there. [...] Not only is thought in the organic world, but it develops there. But as there cannot be a General without Instances embodying it, so there cannot be thought without Signs. [...] Admitting that connected Signs must have a Quasi-mind, it may further be declared that there can be no isolated sign. Moreover, signs require at least two Quasi-minds; a Quasi-utterer and a Quasi-interpreter; and although these two are at one (i.e., are one mind) in the sign itself, they must nevertheless be distinct. In the Sign they are, so to say, welded. Accordingly, it is not merely a fact of human Psychology, but a necessity of Logic, that every logical evolution of thought should be dialogic." (CP 4.551)¹

Peircean semiotics is a kind of phenomenology in which an interpreter's mind is affected by signals coming either from the world and/or from internal memories. The interpreter has no direct access to real objects (Dynamical Objects), but only to their signs conveyed by the signals (Immediate Objects), which means that all representation is due to some kind of collateral experience (CP 8.314). Peirce considers signs as anything suitable to represent anything else. Also, for Peirce, to represent means to be able to transform a sign into another sign called the interpretant of the original sign, which still holds the same power of interpretation. This happens through a process called semiosis, the process by which a sign is transformed into another sign. According to Noth, despite *sign*, *representation*, *mediation*, and *interpretation* being the key terms in the study of semiotic processes, instead of the term *information*, Peirce had much more to say about how signs convey information than is usually acknowledged in contemporary information sciences, and he explains:

¹ Citations to Peirce's works in this paper follow the traditional format used by Peircean scholars. So, instead of Peirce (1931–1958, pp. 120–138) for some pages of the *Collected Papers of Charles Sanders Peirce*, the citation appears as CP x.y where: CP indicates the title, x indicates the volume and y indicates the paragraph.

“Peirce’s information theory does not conceive of information in terms of probabilities of the occurrence of signals, words, or sentences in actual utterances. Instead of probabilities, it calculates the logical quantities of extension and intension of symbols. Furthermore, it does not only calculate the value of the actual information conveyed through new informative propositions but also information as it has accumulated through the implications that symbols acquire in the course of their history. It is, hence, both a theory of knowledge acquisition and a theory of the growth of symbols.” (Noth, 2012)

So, if cognition means the process of acquiring knowledge from the world through a form of information processing, and signs convey information through semiosis toward knowledge acquisition, we postulate that knowledge is encoded through signs, which points to the Peircean semiotics as promising grounding for cognition. And finally, we consider here that the interpreting mind involved in the semiotic processes could be a computational device referred to as an artificial autonomous agent, or simply an agent which is defined by Russell and Norvig (2020, p. 36) as “anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators.” Thus, in this paper, we consider the possibility of an agent, affected by the signals from the world, to use these signals in semiotic processes to acquire knowledge, and use this knowledge to drive its actions.

2. KNOWLEDGE AND CATEGORIES

The general theory of knowledge aims to understand the signification processes of human thought and their relations to the objects of the world as a whole. In its turn, the special theory of knowledge investigates the most elementary concepts used to describe objects, and these concepts are called categories. In this sense, the special theory of knowledge is a theory of categories, and its focus points to the logical origins of the forms of thought and how they arise from the essential laws of thought in confrontation with the experience data (Hessen, 2003, pp. 133–134).

Aristotle was the first philosopher to take care of such matters, and had used language, particularly classes of words, to frame all elements of reality into ten categories: substance; quantity; quality; relatives; somewhere; sometime; being in a position; having; acting; and being acted upon. According to Aristotle, words are things that are said, and it is natural to interpret his system as a classification of words. However he was not primarily interested in words but in the world to which words correspond (Studtmann, 2021).

Due to the skepticism about our capacity to distinguish precise divisions in reality, an important shift from Aristotelian realism to what was called

categorial conceptualism was promoted by Kant. Unlike his precursor, he established his system based on the idea that human thought has no access to *the thing in itself* but only to its appearance or *phenomena*, which leads to the essential categories that govern human understanding or judgement, and judgement is the basis for any possible cognition of phenomena. Thus, to enumerate the forms of possible judgement, he used Aristotelian logic to determine four respects in which one can classify any judgement: quantity, quality, relation, and modality. Moreover, in respect to each class of judgement, Kant recognized three subdivisions leading to twelve categories: Quantity (Unity, Plurality, and Totality), Quality (Reality, Negation, and Limitation), Relation (Inherence and Subsistence, Causality and Dependence, and Community), and Modality (Possibility, Existence, and Necessity) (Thomasson, 2019).

The third great system of categories in the history of philosophy was proposed by Charles Sanders Peirce. In his intent to describe the most universal and elementary categories of all possible experiences he followed the same terminology of Aristotle (*hai kategoriai*) and Kant (*die categorien*), but the result he achieved was even more radical than that of his predecessors. Based on the semiotic processes, he has found only three categories in which all phenomena can be divided, leading to a logical and social theory of sign (Santaella, 2000, p. 7). The following section presents a panoramic view of Peirce's work on semiotics.

3. BASIC NOTIONS OF PEIRCEAN'S SEMIOTICS

Semiotics denotes the study of *signs* and *significant processes* (semiosis). In modern semiotics, the general theory of signs of Peirce postulates semiotics as a universal science, not restricted to human communication. In such sense, signs do not correspond to a specific class of phenomenon but are the elementary components of a kind of phenomenology (Noth, 1995, pp. 39–41) or *phaneroscopy*, which aims to study the universal categories of the *phanerons* (from the greek *phaneros*: visible, manifest, evident, apparent):

“What I term *phaneroscopy* is that study which, supported by the direct observation of phanerons and generalizing its observations, signalizes several very broad classes of phanerons; describes the features of each; shows that although they are so inextricably mixed together that no one can be isolated, yet it is manifest that their characters are quite disparate; then proves, beyond question, that a certain very short list comprises all of these broadest categories of phanerons there are; and finally proceeds to the laborious and difficult task of enumerating the principal subdivisions of those categories.”
(CP 1.286)

Peirce's efforts have reduced all phenomena to only three ontological categories:

— *Firstness* as “the mode of being of that which is such as it is, positively and without reference to anything else” (CP 8.328). Firstness is relate to the ideas of simple potentiality, possibility and independence, a feeling not yet converted to reflection, just a glimpse of reality in the state of pure indetermination. All ideas that are absolutely independent of further ideas to subsist are related to Firstness;

— *Secondness* as “the mode of being of that which is such as it is, with respect to a second but regardless of any third” (ibidem). Secondness points to the experience of space-time, to action, to the experiential reality, to fact, to a perceptible consistency without purpose or judgement, because all these ideas require a relation to other ideas in order to be conceived—any point in space or time requires a connection to another point in space or time in order to be space or time, any action requires an actor, a fact requires an existence where the fact materializes, a consistency requires a reference to what it is consistent to. This is the category for ideas that can only make sense while relating to another idea;

— *Thirdness* as “the mode of being of that which is such as it is, in bringing a second and third into relation to each other” (ibidem). Thirdness corresponds to mediation, to law or habit, to continuity, to purpose and judgement, to thought, and representation because all these ideas are, in themselves, relations between other ideas: mediation is the relation between two other things, a law puts under relation all its possible instances, a habit is nothing more than a learned law, continuity is the principle of recursive mediation between two others, purpose is a glimpse of the future mediating the flow of past to present. Thirdness is the category for ideas that are the own relation between two other ideas or, in other words, when the own relation of two other ideas becomes an idea.

For Peirce, the three categories are related in a triadic way and this relation is irreducible, without boundaries between them: “Not only does Thirdness suppose and involve the ideas of Secondness and Firstness, but never will it be possible to find any Secondness or Firstness in the phenomenon that is not accompanied by Thirdness” (CP 5.90). From this phenomenological framework, Peirce creates the notion of genuine sign, an ingenious explanation conceived from the concepts of thought and representation present in the category of Thirdness:

“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 stands itself to the same Object. The triadic relation is genuine, that

is its three members are bound together by it in a way that does not consist in any complexus of dyadic relations” (CP 2.274).

As pointed by Adele Queiroz (2004, p. 53), the tripod is the best representation of a sign. However, due to the purpose of making explicit some specific aspects of semiosis, this work uses a slightly modified tripod to represent the sign, but, despite its unbalanced form, no dyadic relation must be interpreted (See Figure 2).

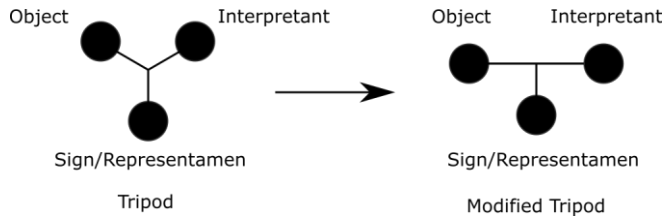


Figure 2: From the tripod to a modified tripod as sign representations

With our modified tripod, we want to emphasize that the sign/representamen, corresponds exactly to the relation between the object and the interpretant, detached as an entity in itself. Or, in other words, the sign is the third that connects the object to the interpretant, mediating between these other two, being the logic mediator between them.

Furthermore, Noth (1995, pp. 43–44) claims that Peirce considers two types of objects: the *Dynamical Object* corresponding to the object outside the sign, something near to the real object, and the *Immediate Object* corresponding to the object inside the sign, near to the representation itself; Moreover, Peirce also considers three types of interpretants, the *Immediate Interpretant* as a semantic potentiality, the *Dynamical Interpretant* as the direct effect produced by a sign in the interpreter which can lead to an action in the world, and the *Final Interpretant* as the one carried so far that an ultimate conclusion was reached, which signifies the possibilities of continuous learning. Peirce used the three categories (Firstness, Secondness and Thirdness) and the triadic relation (Representamen, Object and Interpretant) to create a typology with three trichotomies, as shown in Table 1.

Table 1: Peircean typology of signs, based on Noth (1995, p. 45)

Trichotomy Category	of the representamen	of relation to object	of relation to interpretant
<i>Firstness</i>	Qualisign (Tone)	Icon	Rheme
<i>Secondness</i>	Sinsign (Token)	Index	Dicent
<i>Thirdness</i>	Legisign (Type)	Symbol	Argument

With this typology, Peirce had conceived 10 possible classes of signs: With this typology, Peirce had conceived 10 possible classes of signs: 1. (Rhematic Iconic) Qualisign,² e.g. a non-specific feeling of red; 2. (Rhematic) Iconic Sinsign, e.g. a particular drawing of an ox, carved in a stone, in a cave, recognized by its similarity to an ox; 3. Rhematic Indexical Sinsign, e.g. a subtle non-identified cry, attracting our attention to the person crying; 4. Dicent (Indexical) Sinsign, e.g. a weathercock, as affirming the wind direction here and now; 5. (Rhematic) Iconic Legisign, e.g. a generic diagram, apart from its factual individuality;³ 6. Rhematic Indexical Legisign, e.g. the general idea behind a demonstrative pronoun like “this,” or “that;”⁴ 7. Dicent Indexical Legisign, e.g. a recognized traffic sign, planted in the ground, specifying that a particular traffic law is applied there;⁵ 8. Rhematic Symbolic (Legisign), e.g. a common noun; 9. Dicent (Symbolic Legisign), e.g. an ordinary proposition; and 10. Argument (Symbolic Legisign), e.g. a syllogism.⁶

Following the unbalanced tripod representation introduced here, and considering that each element in the tripod can be either a possibility, an existent or a law, Figure 3 shows the diagrams corresponding to each one of the ten classes of signs proposed by Peirce. White circles in dashed lines means that the element is a mere possibility (Firstness), while grey circles in continuous line correspond to elements that are true existents (Secondness), and black circles in continuous line correspond to elements that are considered as laws (Thirdness).

In addition to the classification of the signs, some important relations between them must be considered, mostly, the relations concerning *composition* and *government*. *Composition* means that a more complex sign might incorporate other less complex signs. In other words, if a sign might be *broken* into parts, these parts *compose* the sign as a whole, e.g., for the Dicent Indexical Sinsign, Peirce says that “[...] is any object of direct experience, in so far as it is a sign, and, as such, affords information concerning its Object. [...] Such a sign must involve an Iconic Sinsign to embody the information

² Parenthesis indicates that some terms can be omitted due to redundancy, e.g. a Qualisign must be Rhematic and Iconic, so it can be referred simply as a Qualisign.

³ This is the case every time an Iconic Sinsign is recognized as an instance of a more general law ruling every single instance of it. The Iconic Legisign is the interpretant of the Iconic Sinsign.

⁴ Do not confound that with the words “this” or “that”, which are Rhematic Symbolic Legisigns. In a technical sense, the Rhematic Indexical Legisign is the interpretant of a Rhematic Symbolic Legisign, after its interpretation. In fact, when we are reading a text and the word “this” appears, it is first an Iconic Sinsign (the ink at the paper), which is then interpreted as an Iconic Legisign (a recognized word), which is further interpreted as a Rhematic Symbolic Legisign, which is finally interpreted as a Rhematic Indexical Legisign.

⁵ The traffic sign, in itself is just a Rhematic Symbolic Legisign, interpreted in the sense of a traffic law. What constitutes the Dicent Indexical Legisign is the fact that this traffic sign is planted in the ground, providing an affirmation that the traffic law, represented by the Traffic Sign (just a Rheme composing the Dicent) is ruling at this location.

⁶ Examples adapted from (Noth, 1995, p. 45).

and a Rhematic Indexical Sinsign to indicate the object to which the information refers.” (CP 2.257). So, every Dicent might be decomposed into a particular set of Rhemes (fragments of the Dicent), which, as a whole, compose it. And *government* means that all Legisigns (Types) exist through their Sinsigns (Tokens or Replicas), e.g., Peirce claims that

“An Iconic Legisign (e.g., a diagram, apart from its factual individuality) is any general law or type, in so far as it requires each instance of it to embody a definite quality which renders it fit to call up in the mind the idea of a like object. [...] Being a Legisign, its mode of being is that of governing single replicas, each of which will be an Iconic Sinsign of a peculiar kind.” (CP 2.258)

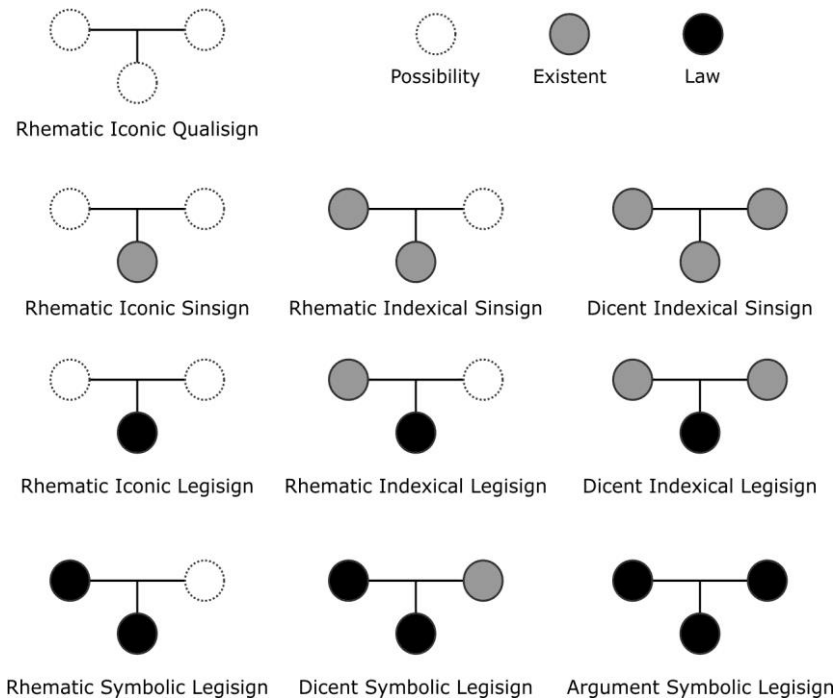


Figure 3: The ten classes of Peircean semiotics according to the proposed diagrammatic representation

Taking into account these relations, Figure 4 aims to represent all possibilities for the ten classes of signs. In this figure we adopted the following convention:

- Continuous arrows stand for *composition* and dashed arrows stand for *government*;
- Legisigns are divided into three types, embracing: LI (Laws of Instantiation), LC (Laws of Coding), and LR (Laws of Reasoning);

- In the *composition* scheme, black arrows (a) mean ordinary composition, purple arrows (b) represent the arbitrary associative laws of coding and orange arrows (c) represent agglutination of sentences to form an argument;
- In the *government* scheme, blue arrows (1) represent genuine necessities, green arrows (2) represent arbitrary necessities and the red arrow (3) represents meta-necessities (laws of laws).

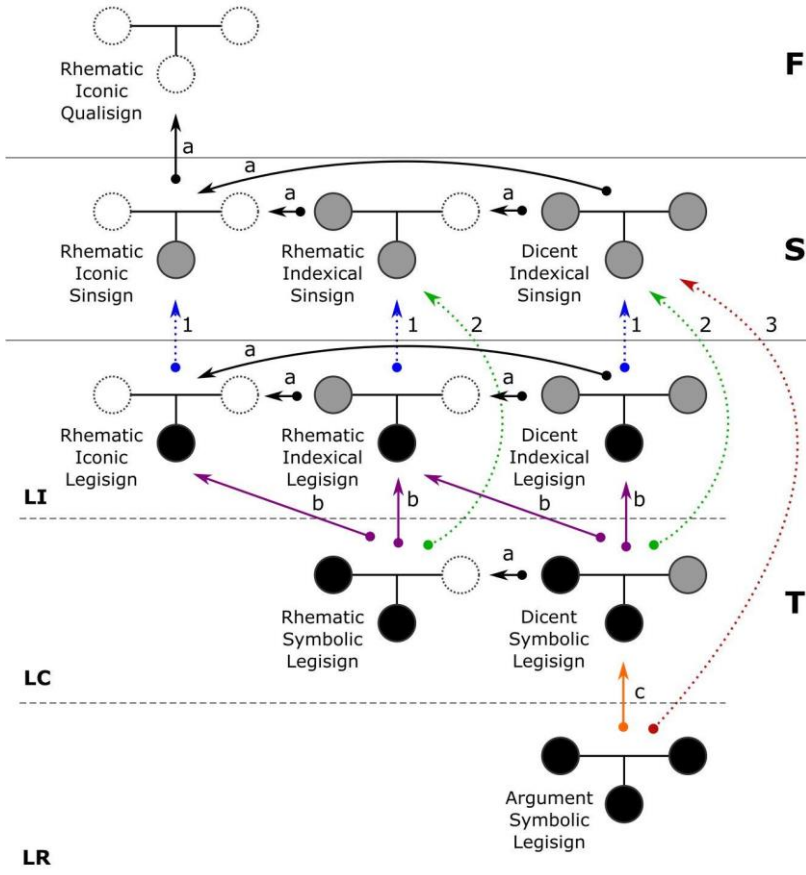


Figure 4: The ten classes of signs and their relations of composition and government (based on Camargo, 2018, p. 45)

Composition and government relations will be resumed in the next sections where LI, LC and LR will be clarified. For now, it is necessary to introduce the notion of semiosis as a process. This means that in the space-time framework, a sign can be interpreted into another sign called its interpretant, and this interpretant, for its time, keeps the same potential of interpretability (to be interpreted into a further sign), making the process continuously going on in the direction of the Final Interpretant. This direction

is merely a tendency as the Final Interpretant cannot be really reached because, if so, it would mean that the absolute truth concerning the object was obtained, which is impossible. Even so, as signs grow, the knowledge about the object increases more and more (see Figure 5). Peirce said about the Final Interpretant that:

“... We must also note that there is certainly a third kind of Interpretant, which I call the Final Interpretant, because it is that which would finally be decided to be the true interpretation if consideration of the matter were carried so far that an ultimate opinion were reached.” (CP 8.184)

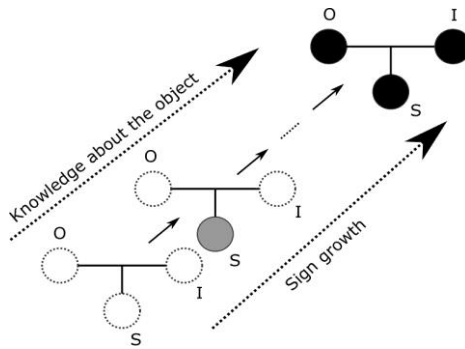


Figure 5: Representation of the semiotic process (semiosis)

Finally, it is important to understand the dynamics by which a Dynamical Object, present at the environment, becomes known by an interpreter’s mind (see Figure 6). The interpreter does not have direct access to it. Instead, this access is always mediated by a sign. But a single sign cannot bring a full acquaintance of the Dynamical Object. It can only bring a partial facet, a particular aspect of this object, which is called the Immediate Object, the parcel of the Dynamical Object, which is conveyed by a single sign. This particular aspect of the Dynamical Object, is consolidated internally in the interpreter’s mind by the generation of the Immediate Interpretant, during a semiosis process. As soon as many different signs bring different aspects of the same Dynamical Object, they are integrated into the Dynamical Interpretant, which can be viewed as the ongoing, best understanding of the Dynamical Object, as long as the interpreter receives signs related to this Dynamical Object. The Final Interpretant is just an ideal target, which will never be achieved, supposing that an infinite number of signs related to this same Dynamical Object could provide a complete understanding of the Dynamical Object. This process is detailed in next section.

4. FROM SIGNALS TO KNOWLEDGE

Considering an *agent* (at this moment, natural or artificial) in relation to its *environment*, we assume here that there is a world outside the agent that cannot be reached by direct access, but only indirectly by means of signs, provided by sensors or internal memories. The agent is equipped with *sensor* devices that can capture and measure certain signals coming from the world or, most precisely, signals that correspond to partial *properties* of the objects of the world that can be possibly sensed. Thus, a *signal* is considered here as the substrate of signs, or as “the vehicle of semiotics” which “is opposed to the sign since it is only its physical embodiment” (Noth, 1995, p. 80). In this sense, a signal is a term of information theory and should not be confused with the signs themselves.

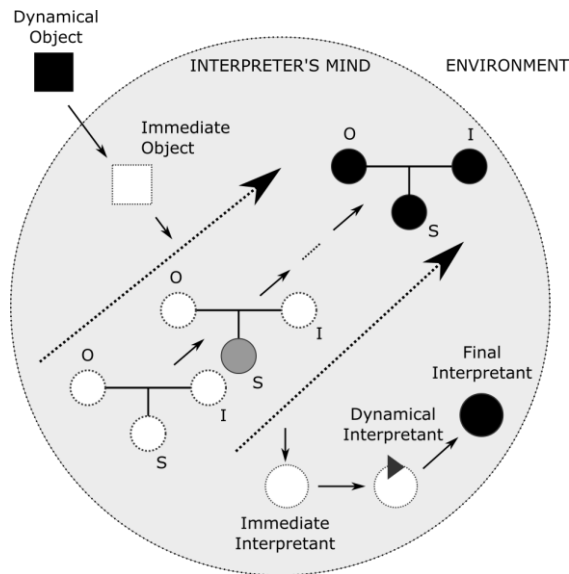


Figure 6: The semiotic dynamics between the interpreter's mind and the environment

The environment is populated by things that will be referred to as *presumed existents* or simply existents, which corresponds to the Dynamic Objects, or the real objects that will be represented by a sign.⁷ When an agent captures the signals coming from a presumed existent and uses them to determine its actions, it plays the role of an interpreter. The term “presumed” is used to reassure that it is impossible to claim its real state of existence.

⁷ In Peirce's words, “That thing which causes a sign as such is called the object (according to the usage of speech, the ‘real,’ but more accurately, the existent object) represented by the sign: the sign is determined to some species of correspondence with that object.” (CP 5.473)

The agent, or interpreter, has a mind that, in the case of artificial agents, corresponds to its control system and memory, which are used to turn signals into signs, transforming the signals information into knowledge (Gudwin, 1999, 2001). Sensors and/or internal memories can be used as sources of signals, by agents, to identify and create compatible models of the world. Besides existents and their properties, things in the real world must actuate following natural regularities or necessities.

Sensors are sources of signals, which should be considered regarding three relevant aspects: *Transduction*, *Intensity* and *Position/Orientation*. *Transduction* is a unique capability of sensors, in establishing a natural analogy between different properties of existents with a prototypical property to be used internally by an agent, for processing information within the agent's mind. For each different sensor, a certain kind of property is being measured and translated to this prototypical property, which can be stored and interpreted, e.g. chemical-electric sparks in biological organisms or digital numbers stored in computer memories. *Intensity* corresponds to the magnitude of the signal, compared to a reference physical property, which can be understood as relative numbers that can change as time passes. Finally, *Position/Orientation* has to do with the fact that sensors are space located, so the signal they generate maintains a spatial relation between sensed properties and the agent's own position/orientation. Thus, at each time step, each sensor generates a signal integrating intensity combined to position/orientation, which is then accumulated in a windowed queue, in order to register the passage of time, creating a spatial-temporal dynamics in the manifold of senses. In the interpreter's mind, these signals are conveyed into signs. The most elementary ones are the Qualisigns, which stands in isomorphic relation to the properties of the presumed existents,⁸ remembering that this is always a partial process as the presumed existent cannot be captured in its wholeness.

4.1. Indexicality and iconicity in sensors

Most Peircean semioticians consider sensors as sources of indexical signs. And there is a reason for that. Peirce himself had written that:

“For the acceleration of the pulse is a probable symptom of fever and the rise of the mercury in an ordinary thermometer or the bending of the double strip of metal in a metallic thermometer is an indication, or, to use the technical term, is an index, of an increase of atmospheric temperature, which, nevertheless, acts upon it in a purely brute and dyadic way. In these cases, howev-

⁸ The terms property and quality can be used to the same signification, but in this paper, the term property is used in reference to the features of the existents of the real world and the term quality is used in reference to the signs

er, a mental representation of the index is produced, which mental representation is called the immediate object of the sign; and this object does triadically produce the intended, or proper, effect of the sign strictly by means of another mental sign; and that this triadic character of the action is regarded as essential is shown by the fact that if the thermometer is dynamically connected with the heating and cooling apparatus, so as to check either effect, we do not, in ordinary parlance speak of there being any semeiosis, or action of a sign, but, on the contrary, say that there is an 'automatic regulation,' an idea opposed, in our minds, to that of semeiosis. For the proper significate outcome of a sign, I propose the name, the interpretant of the sign." (CP 5.473)

Nevertheless, in this work, we postulate that, regarding sensory processes, there are two possible interpretations about the types of signs sensors can produce. The first interpretation matches the general consensus of indexicality: it is evident that a mercury thermometer acts indicating another object's temperature (the temperature of the air surrounding the thermometer). But what can be told if we are feeling this temperature by ourselves, using the ability of our skin to feel it, for that purpose? It is important to understand that both the mercury thermometer and our skin cells are temperature sensors. In fact, they are both thermometers, maintaining certain isomorphism between the properties of the world and the qualities perceived. The difference is that the mercury thermometer is an external sensor, to which I might have my attention driven, while in the case of my skin, I am directly connected to it. So, sensors might differ depending on the fact of being (or not) a part of the agent. Under this particular perspective, sensors can also be understood as sources of Iconic Signs (Gudwin, 2014). Even when thinking about thermometers and measured temperatures, both instances can be detected. If one looks to a mercury thermometer and starts making conjectures about the intensity of the measured temperature, comparing the size of mercury column to the temperature being felt by their skin, they are involved in an indexical process, but if one touches a hot surface with their own hands, some similar conjectures could be done, but they would have started from a different type of signs, the Iconic Sinsigns.

In a very careful analysis of Peirce's extensive and intricate system of signs classification, Santaella (2020, pp. 293–306) enhanced her earlier concept of the six degrees of iconicity (Santaella, 1996), which lead to the correspondence with three of the ten classes of signs, the Qualisigns, the iconic Sinsigns, and the iconic Legisigns. From her point of view, the iconicity degrees go from Pure Icons (one degree) to Actual Icons (two degrees), and from them to Hypoicons (three degrees).

Following Santaella, the Pure Icon is a quasi-sign, or a sign reduced to a monadic state as it is something merely mental. It's something that does not even become realized as an idea, it stays in the undefined realm of mere

possibility, and she points to Peirce's own words "For in precision of speech, Icons can represent nothing but Forms and Feelings. [...] No pure Icons represent anything but Forms; no pure Forms are represented by anything but Icons" (CP 4.544). However, when considering outward objects presented to one's mind, a dyadic relation is established through perception process, and this change represents the passage from Pure Icons to Actual Icons. Now, it is not a case of merely mental action but a connection between outer and inner worlds that brings into relation the objects of the world and the mind, it is an act of perception. In this scheme, both Pure Icons and Actual Icons are related to Qualisigns (Santaella, 2020).

On the other hand, the Hypoicons are Iconic Signs operating in the level of Secondness and Thirdness (Sinsigns and Legisigns). The Hypoicons can be divided into Images, Diagrams, and Metaphors according to the mode of Firstness they participate in. Images are the signs that participate in simple qualities (Firstness); Diagrams are those signs that represent relations (Secondness); and Metaphors are those signs that represent parallelism in something else (Thirdness) (CP 2.277). Stjernfelt (2007, pp. 293–306) introduces the instances of hypoicons as follows:

"Images in this restricted, technical meaning of the word are similar to their object due to some simple quality (color, shape, tonality, size ...); diagrams are all similarity-based signs which refer to their object by means of some skeletal analysis of the object into mutually connected parts. The diagram consists of a sketch-like anatomy of its object—as the most ordinary examples one may point to function diagrams, cake diagrams, column diagrams, matrices—but also, cf. below, a much larger set of icon types. Metaphor, finally, is the picture type which refers to its object via the intermediary of a third object."

An important aspect of Hypoicons is their condition of compositionality. An image can be understood as a topological composite of qualities, or a bundle of qualities that, acting together, shapes the objects of the world; a diagram, in its turn, is a composite of relations between different parts of an object; and, finally, a metaphor exposes some kind of parallelism composition represented by a certain type of law that connects objects not by direct affection, but through some kind of idea.

In this context, embodied sensors can be understood as source of Iconic Metaphors, mapping the objects of the world as an analogy of the properties of such objects (Gudwin, 2014). Figure 7 represents the action of a generic sensor functioning as an interface between the world and the interpreter's mind.

Thus, we might consider icons as the most basic bricks of knowledge that can affect an agent and, as pointed by Peirce: "For a pure icon does not draw any distinction between itself and its object. It represents whatever it may

represent, and whatever it is like, it in so far is. It is an affair of suchness only” (CP 5.74). Being so, the evanescent background of Qualisigns must be developed to most complex signs, first to Hypoicons, which represents figures detached from the background, and from them to even more developed signs as indexes and symbols.

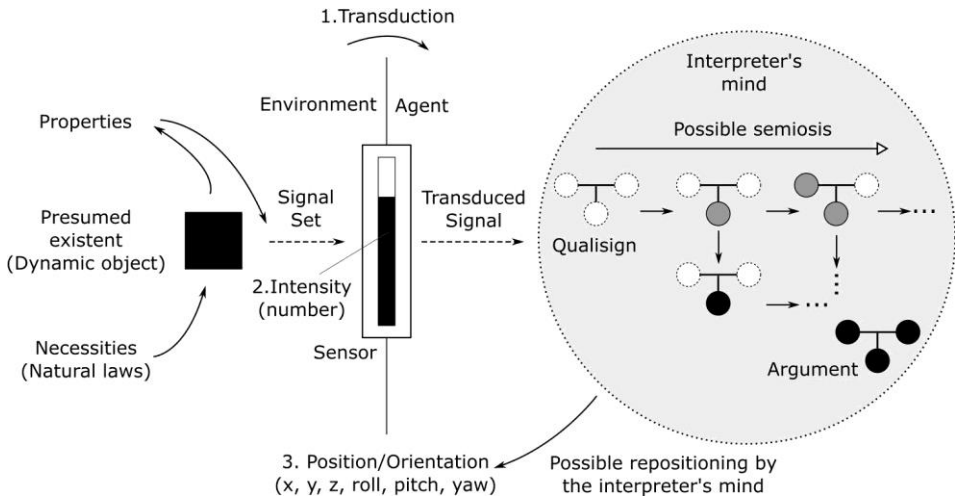


Figure 7: The process of signal transduction and its sign representation in the interpreter's mind. Transduced signal occurs on a material substrate according to the nature of the agent (chemical-electric sparks, electric pulse, discrete numbering, etc)

4.2. Indexicality and iconicity in sensors

4.2.1. Firstness

Nothing can be claimed for sure about both the existents and the laws ruling their natural interactions. But, due to these laws, existents show some properties and regularities that produce a signal set that, possibly, can be captured by agents equipped with appropriate sensors, e.g., an existent that has the property of reflecting electromagnetic waves in a band between the infrared and the ultraviolet can be perceived by a regular human being. Human eyes have the capacity to transduce photon beams to chemical-electric pulses (transduced signal) that subsidize the agent to create a mental map of the existent. This representation is not a high fidelity copy of the original, but, as written by Vieira (1994, p. 16): “the more an organism can generate environment isomorphic mapping the more it will be near of ‘ideal objectivity’, and more capable of surviving it will be.”

Thus, considering Peircean semiotics, the mapping process generates the Immediate Objects, but, in this first moment, it is just a glimpse of the world, a diffuse background where no detached figure is yet in mind. At this

moment, only Qualisigns affect the agent mind. This is the domain of Firstness, where everything is a mere possibility. It represents the most basic agent–environment interface, and it is the first step of the process toward getting knowledge about the world, e.g., someone stands on an open field with a small house at the left and there is a weathercock on the house’s roof, but at this first moment, the eventual interpreter is only able to feel sensory traces of them, through the manifold of senses. Everything is just a diffuse background of evanescent qualities (See Figure 8).

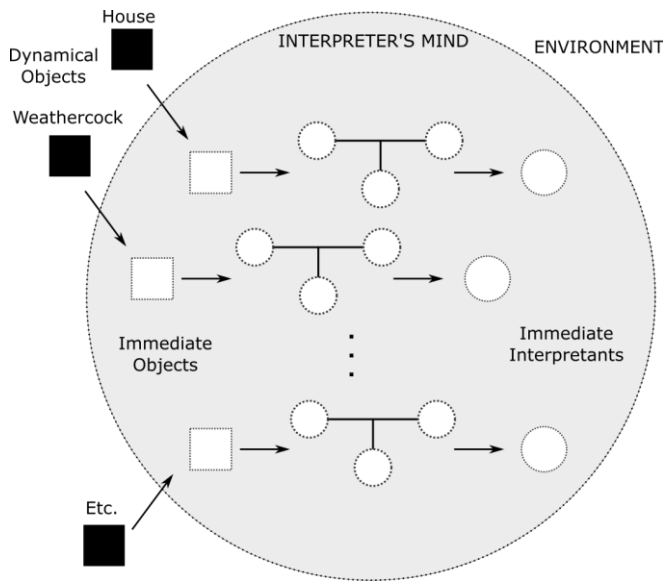


Figure 8: Representation of Firstness, when only Qualisigns affect the interpreter’s mind, which is surrounded by a diffuse background of evanescent qualities that generate only Immediate Interpretants as semantic potentialities

4.2.2. Secondness

If Firstness corresponds to mere possibilities, the domain of Secondness is where existents became actualized as figures detached from the background. Now, there are three classes of sinsigns affecting the interpreter’s mind: the Rhematic Iconic Sinsign, the Rhematic Indexical Sinsign and the Dicent Indexical Sinsign. The first one corresponds to the impressions of an existent (a thing is perceived), it is a Sinsign because it is, in itself, a part of existence, but the Object and the Interpretant remain as mere possibilities. It is an Icon because it is recognizable due to its similarity with its object. And it is a Rheme, because it is only a part of a possible proposition; the second corresponds to the apprehension of the existent and to the relations that this existent maintains with other existents. It is an Index because it drives attention to the existent it indicates, but the Interpretant remains as

a mere possibility; and the third, finally, turns the Interpretant into a fact, or a judgement (about something), it is the expression of the existent's predicates, a composition that leads to an episode of knowledge.

Then, considering the process of impression-apprehension-expression in the example of a distracted person standing on an open field, suddenly, a gentle breeze moves the arrow of the weathercock and a brief high-pitched metallic sound reaches the agent's ears. The sound makes something to be detached from the background. It is just the primary manifestation of an existent represented by Rhematic Iconic Sinsigns (impression). On a second moment, the attention of the interpreter turns his eyes to the weathercock, Qualisigns and Rhematic Iconic Sinsigns still actuate but now they are involved by Rhematic Indexical Sinsigns that maintain the semiotic process going on: the sound points to the weathercock, which points to the wind (apprehension). Now, the interpreter's mind are populated by Dicent Indexical Sinsigns, which allow the mind to start making judgements about the wind, about its speed and direction, possibly, its temperature could indicate a change in the weather conditions and the necessity to find a shelter, etc (expression). Semiosis keeps going on as new Sinsigns affect the agent, working in the composition of an episode of knowledge (See Figure 9).

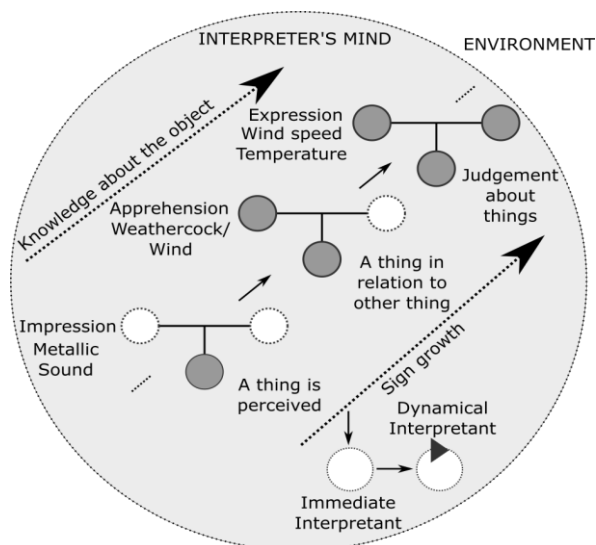


Figure 9: Representation of the Secondness, a perceived sound makes a figure to detaches from the background (the weathercock), which leads the attention of the interpreter to make judgements about the weather. At this moment Immediate Interpretants persist but they are accompanied by Dynamical Interpretants as the direct effect produced by a sign

However, if all fact that takes place in the Secondness just represent unprecedented events with no possibility of new occurrences in the future, no regularity, or law, would be recognized, and, consequently, nothing would

be converted to knowledge. In this sense, each Sinsign must be a replica (or a Token) of a Legisign. “The Replica is a Sinsign. Thus, every Legisign requires Sinsigns. But these are not ordinary Sinsigns, such as are peculiar occurrences that are regarded as significant. Nor would the replica be significant if it were not for the law which renders it so” (CP 2.246). Therefore, judgements are possible only due to the actuation of another category: Thirdness.

4.2.3. Thirdness

Recurrent events actualized in Secondness are specific instances of general laws. Sinsigns (Tokens) are governed by Legisigns (Types). There are six classes of Legisigns, and they will be introduced here divided into three subclasses in accordance with the types of laws they represent: Laws of Instantiation (LI), Laws of Coding (LC) and Laws of Reasoning (LR).

Laws of Instantiation are represented by Rhematic Iconic Legisigns, Rhematic Indexical Legisigns and Dicent Indexical Legisigns, each of them corresponding respectively to the types of their tokens: Rhematic Iconic Sinsigns, Rhematic Indexical Sinsigns and Dicent Indexical Sinsigns. These laws represent one dimension of what Hoffmeyer calls code-duality, the dimension of the continuous:

“As analog [continuous] codifications, organisms recognize and interact with each other in ecological space, whereas as digital [discrete] codifications (genome), they are passively carried forward in time from generation to generation [...]. Seeing from this perspective, life must be understood as *semiotic survival*—survival via a fundamental code-duality” (Hoffmeyer, 2008, p. 80)

If the continuous dimension is represented by the Laws of Instantiation, the discrete dimension of code-duality—which Hoffmeyer exemplifies through genome—is represented by the Laws of Coding: Rhematic Symbolic Legisigns and Dicent Symbolic Legisign. The rhematic character of the first one indicates one unique piece of information as a word, and the dicent character of the second demonstrates the connection of particular pieces of information to a predicate as a sentence. The Laws of Coding can be taken as the elements of a table, where two columns contain, each one, two different sets of terms—set T_1 containing the terms $t_{11}, t_{12}, \dots, t_{1n}$, that correspond to words; and T_2 containing the terms $t_{21}, t_{22}, \dots, t_{2n}$ that correspond to predicates, and each line represents the imposed, or arbitrary, relation between these terms (t_{11} points to t_{21} , t_{12} points to t_{22} , ..., t_{1n} points to t_{2n}). Finally, the Laws of Reasoning, Argument Symbolic Legisigns, are responsible to mediating the associative relations between continuous and discrete codes, acting as a set of meta-laws to consolidate knowledge and to allow learning of new habits (See Figure 10).

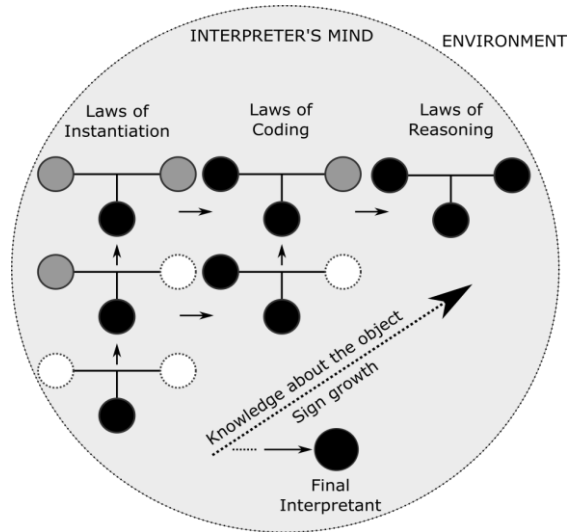


Figure 10: Representation of the Thirdness, and its three types of laws: Laws of Instantiation (continuous, classification), Laws of Coding (discrete, consolidation) and Laws of Reasoning (continuous/discrete, learning, laws of laws). It is the moment for the presence of the Final Interpretants that work as a tendency that will not be achieved but promote knowledge

5. THE WHOLE PROCESS OF KNOWLEDGE ACQUISITION THROUGH SIGNS: FROM THE THREE WORLDS OF POPPER TO THE WORLDS OF IDEAS AND THE FRAGMENTS OF REALITY

This section introduces some preliminary thoughts about reality based on possible relations between Popper and Peirce. It presents a digression that would help future development in Artificial Intelligence. Despite its speculative character, we consider it relevant to introduce the theme in this paper.

5.1. The three worlds of Popper

Trying to represent reality, Karl Popper introduced the concept of three worlds, which were called world 1, world 2, and world 3. The original idea of Popper was not to establish three independent parts of reality, but three levels of it that interact and affect each other. In his own words:

“There is, first, the world that consists of physical bodies: of stones and of stars; of plants and of animals; but also of radiation, and of other forms of physical energy. I will call this physical world ‘world 1’. [...] There is, secondly, the mental or psychological world, the world of our feelings of pain and of pleasure, of our thoughts, of our decisions, of our perceptions and our observations; in other words, the world of mental or psychological states or processes, or of subjective experiences. I will call it ‘world 2’. [...] By world 3 I

mean the world of the products of the human mind, such as languages; tales and stories and religious myths; scientific conjectures or theories, and mathematical constructions; songs and symphonies; paintings and sculptures. But also aeroplanes and airports and other feats of engineering.” (Popper, 1972, p. 143)

Popper divides world 1 into the world of non-living physical objects and the world of biological objects, claims that world 2 could be subdivided in various ways, e.g. into conscious experiences and dreams, and points that from world 3 many possible sub-worlds can be distinguished, e.g. the world of science from the world of fiction; and the world of music and the world of art from the world of engineering.

If the idea of knowledge is conceived as the set of representations that can map reality to the agent’s mind, and this knowledge is the element that allows cognition to perceive the world and transform it in the benefit of the agent, then the three worlds of Popper can be understood as the things that can be the objects of cognition and also everything that can be known, being the world 1 as the world of knowable things, world 2 the world of the things already mapped inside the human mind, and the world 3 as the result of the human cognition that affects back the world 1.

The three worlds of Popper, in some sense, correlate to the categories of Firstness, Secondness, and Thirdness of Peircean semiotics since world 1 points to the objects of the reality that can be possibly perceived, world 2 to things that take place inside the human mind, and world 3 to things that can be created by humankind and creation presupposes the use of laws to compound complex objects. But, the similarity ceases immediately as Popper considers these worlds in a pluralistic scheme:

“What have I as a pluralist to say to the materialist monist and to the dualist? First of all, I am, like the dualist, prepared to agree with much that the materialist monist says; in fact, with everything except his denial of a world 2 of experiences and of a world 3 of abstract objects such as the Fifth Symphony. And similarly, I agree with all that the dualist says, except with his implicit belief that the Fifth Symphony is to be identified with our experiences of hearing it, or of remembering it.” (Popper, 1972, p. 148)

Peirce’s understanding of reality, instead, claims absolute continuity. He says that “yet, the reality of continuity once admitted, reasons are there, divers reasons, some positive, others only formal, yet not contemptible, for admitting the continuity of all things” (CP1.170). And claims that “now the doctrine of continuity is that all things so swim in continua” (CP 1.171). So, considering Popper’s effort to divide reality into worlds, but trying to complement this approach with Peirce’s categories in continuous relations, next subsection will propose another division of reality into worlds.

5.2. The Worlds of Ideas and Fragments of Reality

All systems of categories are attempts to classify the kinds of elements that appear in the mind. These elements can be addressed, individually, as ideas, and elementary ideas can be linked together in order to generate more developed ones. Considering Peircean semiotics, signs are the elements that allow ideas to appear in the mind, and semiosis is the process that relates one idea to another. Popper's world 1 (and possibly part of world 3) can be viewed as the world around us, our environment. Both world 2 and (part of) world 3 can be viewed as worlds related to things appearing in our mind. World 2 include the elements in our mind that can be put in correspondence with elements in world 1. World 3 include the creations of our mind that extrapolate world 1. In this work, we propose a different (but somewhat related) conceptualization, inspired in Peircean ideas. We focus first on what we might refer to the three Worlds of Ideas, categorizing the three different kinds of ideas that can appear in our mind.

These are the World of Possibilities (related to the category of Firstness), the World of Existence (related to the category of Secondness) and the World of Laws (related to the category of Thirdness). Within each of these worlds, we also have embedded three other worlds that are related to three different levels in which we can describe the reality around us (Popper's world 1). These are the World of Senses, the World of Things, and the World of Scenes. Figure 11 aims to represent this intricate organization.

The World of Existence is somewhat equivalent to Popper's world 1. In fact, it is not exactly world 1, but the ideas in our mind regarding world 1. It includes everything we believe is really happening around us, our best guess of what is real, things we may repute as real facts, what we might call "the truth". Feelings of this world are feelings we really felt, or feelings we are currently feeling. Things of this world are things we believe are really there, things we believe are real, in the past or in the present. Scenes of this world are scenes we experienced by ourselves, or which by the testimony of others we believe they really happened, or are happening right now. In summary, the World of Existence includes our naive understanding of what we might call reality, or the real world, but which might better be called actuality or existence. We decided to start our description of the three Worlds of Ideas by the World of Existence, because usually this is the point of contact of our mind with reality. But, as pointed out by Peirce, the reality is more than the World of Existence. It includes also the World of Possibility and the World of Laws. In fact, according to Peirce, the World of Existence is related to Secondness.

Now let's investigate the other two worlds of ideas. The World of Possibility (domain of Firstness) is the world including everything that is possible, or at least we believe is possible, in the world of existence. It includes imagination, speculation, hypothesis, plans for the future, exploration of

scenarios, etc. The World of Possibility is the world where fiction and imagination take place. It is the world that works as the playground of the mind, where we situate things we know are not part of existence, but (we speculate) might be. Feelings in this world are just possible feelings, not those that really happened, or are happening. We can think of the World of Possibility as either atemporal, out of time, or as in the future, something that might possibly happens in the future. Things in the World of Possibility are just imaginary things, things that might exist, but without any commitment with things that really exist. Scenes in the world of possibility can be the recreation of scenes that really happened at the world of existence, but without any implication that they really happened. The World of Possibility is where we situate our interpretations, when we read a book of fiction, when someone tells us an invented story. We know they are not real, even though, they might be. While interpreting text, the World of Possibility is where we situate things when we talk about “a horse,” or “a red apple.” It is not a particular horse we get in touch during our life, but just a possible horse. It is not a particular apple we found, or might find, nor with a particular kind of red, but just any possible red.

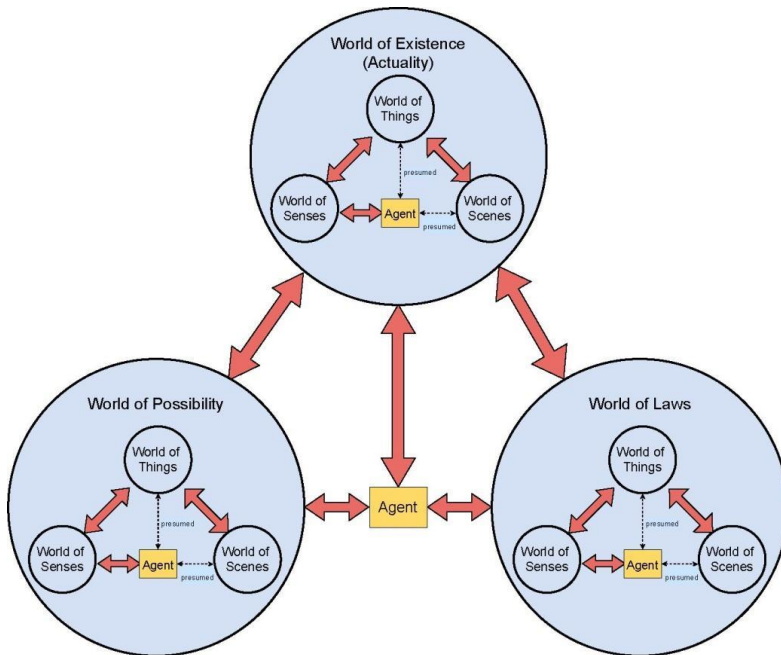


Figure 11: The worlds of ideas and the fragments of reality

Sane persons, while thinking, are fully capable of making the distinction of what pertains to the World of Existence, and what pertains to the World of Possibility. Illusions are things we erroneously situate in the World of

Existence, but are actually part of the World of Possibilities. Also, people with mental problems might make a confusion between these two worlds. In fact, anyone might be subject to this mistake, in some situations. Nevertheless, in its process of interpreting signs, an agent should be always classifying things as being either a part of the World of Existence, or of the World of Possibility. Besides that, everything in the World of the Existence might have a dual in the World of Possibility, as everything that really is, must first, be possible.

Finally, the last of the three Worlds of Ideas is the World of Laws (domain of Thirdness). There reside all the ideas regarding concepts, categories, types, habits of behavior, patterns, learning algorithms, rules, etc. Even though the concept of law is something that we can intuitively understand, at the same time it is quite difficult to precisely define. A law is a generic term we use to abstract an idea that mediates the relation between other ideas. A law is the reason by which many other different ideas are bounded together in becoming instances of it (the law). In set theory, it is the membership rule that defines if an element is (or is not) a member of a set. In physics, laws capture the generality of phenomena and allow them to be described in terms of things that keep repeating themselves in different situations. In human social interactions, laws are human arbitrations for enforcing certain habits of conduct among a group of people. The concept of law embraces the idea of generality, of an implicit reason for putting together things that might have their own individuality, but at the same time share some kind of commonality. Thus, in the World of Laws we locate all the concepts governing all other kinds of ideas.

These concepts govern both the ideas pertaining the world of possibility and the World of Existence. These are meant to be instances of these concepts. So the feelings in the World of Laws are all the categories of feelings (or senses) that are related to the feelings in the World of Possibilities and the feelings in the World of Existence. The things in the World of Laws are all the categories of things that are related to the things in the World of Possibilities and the things in the World of Existence. And the scenes in the World of Laws are all the categories of scenes that are related to the scenes in the World of Possibilities and the scenes in the World of Existence.

Given that, we can see that the same three Worlds of Senses, Worlds of Things and World of Scenes do appear in the World of Possibilities, the World of Existence and the World of Laws. But the ideas there, besides sharing some commonality, are not the same. We refer to these three worlds as the Fragments of Reality, in three different contexts. In terms of existence, the existence can be fragmented (segmented) into scenes, involving different things, where different (sensed) properties might change (or remain constant), along time passes.

Now, permeating all the three Worlds of Ideas (and their Fragments of Reality), we have signs, representing the different aspects of reality. The identification of classes of signs, separated into three categories, presupposes that all types of ideas can be encoded to express these different aspects of reality.

In a natural or artificial agent, all these signs are supposed to manifest themselves either on signals coming from sensors and actuators, or in signals stored into internal memories. In natural agents, these signals might be chemical/electrical signals located in specific body cells, like e.g. neurons, or muscular cells. In artificial agents, we might generalize that all the signals are stored into computer memories, given that some memory addresses are in fact mapping into the agent's sensors/actuators. Through its sensors and actuators, the agent can only reach the World of Senses, leaving the World of Things and the World of Scenes to be always presumed, even in the World of Existence and in the World of Possibilities. Also, not all of the possible/existing properties can be captured by the agent. So, depending on the nature of the agent and the capacity of its sensors, different properties might be sensed/represented. The property in itself will depend on the sensor/actuator where the signal comes from.

In this scheme, the signals coming from the agent's sensors represent different features of the Dynamical Objects supposed to exist in the reality. These dynamical objects are the fragments of reality being represented by signs. They might be senses, things or scenes, depending on the signs representing them. The most basic kind of sign, the *Qualisign*, is only capable of representing a sense in the World of Possibility. It is used to represent just a hypothetical sense (an imaginary or generic one). In order to represent a sense that was really sensed, by an agent, a sense at the World of Existence, we might require a *Rhematic Iconic Sinsign*, governed by a *Rhematic Iconic Legisign* (which represents a law at the World of Laws). When an agent captures, in a given instant of time, a particular measuring from a particular sensor, this causes the creation of a Rhematic Iconic Sinsign at the agent's internal memory. As soon as this Rhematic Iconic Sinsign is recognized as an instance of a Rhematic Iconic Legisign, the dynamics of the World of Senses is completed. Despite the status of Secondness of the Rhematic Iconic Sinsigns, their presence as mere possibilities, as becoming from a hypothetical Thing, from the World of Possibilities, denotes their iconic condition.

Things can be represented as bundles of properties. So, in order to represent things, either from the World of Possibilities or from the World of Existence, we need to use *Rhematic Indexical Sinsigns* governed by *Rhematic Indexical Legisigns*. They are indexes, because they do not have in themselves the properties, but they point to icons that represent these properties. So, each Rhematic Indexical Sinsign will be pointing to multiple Rhematic

Iconic Sinsigns, if this thing is from the World of Existence, or Qual- isigns, if it represents a thing at the World of Possibilities. So, in fact, a Rhematic Indexical Sinsign is a bundle of Rhematic Iconic Sinsigns, representing multiple senses at the World of Existence, or a bundle of Qualisigns, representing multiple senses at the World of Possibilities. Rhematic Indexical Legisigns are laws, from the World of Laws, used to represent classes of things.

Finally, the agent can make judgements about the things, their properties and how these properties change over time forming scenes. In order to represent these scenes and other kinds of judgment about the particular state of any particular thing being a part of a scene, we might use *Dicent Indexical Sinsigns* governed by *Dicent Indexical Legisigns*. These are indexes because they point either to Rhematic Indexical Sinsigns representing the things participating at the scene, or to Rhematic Iconic Sinsigns or to Qualisigns representing a particular sense, from the World of Possibilities or the World of Existence, while being used or not to characterize the scene. This scene might be from the World of Possibilities, while being a hypothetical (generic or imaginary) scene, or from the World of Existence, while being a scene that really happened. Dicent Indexical Legisigns are laws representing the many classes of scenes sharing some kind of commonality. While perceiving a scene evolving in time, the agent creates a Dicent Indexical Sinsign. As soon as this Dicent Indexical Sinsign is recognized as being an instance of a Dicent Indexical Legisign, the class of scene just happening is recognized. This dynamics makes the World of Scenes.

The three worlds representing the Fragments of Reality: the World of Senses, the World of Things, and the World of Scenes are not confined to a specific World of Ideas. They can be perceived inside the World of Possibilities, the World of Existence, and the World of Laws. What differentiate the Fragments of Reality inside each World of Senses and the World of Things is the combined status of all necessary sensed qualities needed to generate the representation of specific things, and then how these things are involved in the representation of scenes. For example, the idea of a horse involves a bunch of qualities, like form, color, being located in a specific space-time, etc. When all (or at least some of) these qualities are undefined or vague, the idea represents a horse in the World of Possibilities. This might be a generic indefinite horse, or maybe a fictional horse. When all these qualities are defined, the idea represents an existent horse, or a specific horse in the World of Existence.

Rhematic Iconic Legisigns, *Rhematic Indexical Legisigns* and *Dicent Indexical Legisigns* are all cases of Laws of Instantiation. These laws are used to represent classes or types, governing instances of different fragments of reality. Beyond the Laws of Instantiation, there are two other classes of signs, the *Rhematic Symbolic Legisigns*, and the *Dicent Symbolic Legisigns* that are cases of Laws of Coding. They govern their Replicas in

such a way that the first represents symbols to other things around (like a word or a group of words not forming a complete sentence), and the second represents symbols of judgments about scenes, things and senses (like a complete sentence). The first governs Rhematic Indexical Sinsigns, and the second governs Dicent Indexical Sinsign, which makes to place them, respectively, in the World of Things and in the World of Scenes. Finally, rests the *Arguments* (Argument Symbolic Legisigns), which are learning rules (Laws of Reasoning) that govern Replicas of Dicent Indexical Sinsigns, which corresponds to the Worlds of Scenes.

The result of the division of reality into worlds based on the theory of signs of Peirce, even being a bit intricate, introduces a new approach to study knowledge acquisition in a continuous framework, which can direct the researchers' attention to once hidden pieces of evidences to conceive better models of the mind.

6. FROM KNOWLEDGE TO ACTION

6.1. Energetic Interpretants, Actions and Creativity

In last section, two levels of knowledge, based on Peircean Semiotics, were considered: one driving the acquisition and establishment of knowledge, mediated by Laws of Instantiation and Laws of Coding, and one allowing learning, mediated by Laws of Reasoning, leading to habit changes. Now it is time to address how semiosis can be related to actions.

Semiosis is the process by which a sign causes an effect, its interpretant. According to Peirce's earlier ideas, this interpretant was supposed to necessarily be another sign, generating a scheme of infinite semiosis, in which an interpretant is also a sign and, being so, another interpretant should be present in an unending process. But Short (2004) points out that, after 1904, Peirce expanded his original point of view, proposing that an interpretant need not always be another sign. In this expanded comprehension, even though the genuine effect of a sign is to generate another sign (a thought-sign), degenerate cases of interpretants might be actions or feelings as well. Peirce's claims that:

“... Taking sign in its broadest sense, its interpretant is not necessarily a sign. [...] We may take a sign in so broad a sense that the interpretant of it is not a thought, but an action or experience, or we may even so enlarge the meaning of sign that its interpretant is a mere quality of feeling. A Third is something which brings a First into relation to a Second. A sign is a sort of Third. How shall we characterize it? Shall we say that a Sign brings a Second, its Object, into cognitive relation to a Third? That a Sign brings a Second into the same relation to a first in which it stands itself to that First? [...] A sign therefore is an object which is in relation to its object on the one hand and to

an interpretant on the other, in such a way as to bring the interpretant into a relation to the object, corresponding to its own relation to the object. I might say 'similar to its own' for a correspondence consists in a similarity; but perhaps correspondence is narrower." (CP 8.332)

Following Short (2004) explanation, Peirce established a new classification of the interpretants, considering that feelings are monadic, actions are dyadic, and signs are triadic, and, in 1907, Peirce called these types of interpretants emotional, energetic, and logical. In Peirce's words:

"This 'emotional interpretant,' as I call it, may amount to much more than that feeling of recognition; and in some cases, it is the only proper significate effect that the sign produces. Thus, the performance of a piece of concerted music is a sign. It conveys, and is intended to convey, the composer's musical ideas; but these usually consist merely in a series of feelings. If a sign produces any further proper significate effect, it will do so through the mediation of the emotional interpretant, and such further effect will always involve an effort. I call it the energetic interpretant. The effort may be a muscular one, as it is in the case of the command to ground arms; but it is much more usually an exertion upon the Inner World, a mental effort. [...] In advance of ascertaining the nature of this effect, it will be convenient to adopt a designation for it, and I will call it the logical interpretant, without as yet determining whether this term shall extend to anything beside the meaning of a general concept, though certainly closely related to that, or not." (CP 5.475-6)

So, following this new trichotomy introduced in 1907, we can assume that every action is the energetic interpretant of a previous sign, processed by an agent in its behavioral process. We can split the process of action into three different moments or stages. In the first moment, an action is *proposed*. In a second moment, an action might *be selected*, among many possible actions, which might have been first proposed. Finally, the selected action is then *performed*.

Considering the different means by which an action might be proposed, and applying Firstness, Secondness and Thirdness, we might reach three different kinds of actions:

- Actions of Firstness are spontaneous kinds of actions, usually embedded with some sort of randomness with an exploratory disposition. This kind of actions induces strategies of trial and error that lead to start finding solutions to unknown situations. The main characteristic of an Action of Firstness is that its proposal (or determination) is completely independent of the present situation.
- Actions of Secondness are reactive actions triggered by a sensor or an internal signal. They are reactions to either external or internal stimuli, usually the fruit of a habit of conduct, triggered only due to the per-

ception of an immediate present. So, its proposal (or determination) is a function of the present situation.

- Actions of Thirdness are motivated actions, which are the most complex of them, requiring both the perception of the immediate present and an expected desired future state, which the agent is supposed to achieve. In order to perform Actions of Thirdness, an agent needs to have at least some model of the effect of possible actions when applied to the present state, and the new state to be achieved if these actions are applied. Then, a path of actions (a plan) might be conceived, moving the present situation to the future desired state. So, its proposal (or determination) is a function both of the present situation, and the desired future state the agent is supposed to reach.

We assume that multiple processes of semiosis happening inside an agent's mind might propose a whole set of actions, which will compete to each other in order to be selected, such that the chosen one, in any particular instance of time, will then be performed, or executed. Actions of Firstness will be proposed every time a certain level of doubt is achieved, or the agent is engaged into some sort of exploratory behavior, particularly when the current situation is unclear, or the agent is not certain in what to do. Actions of Firstness might be important during the process of learning by trial and error, such that the agent can build a behavioral model, and create internal habits of conduct. Actions of Secondness usually are the case when such habits are already defined, and the agent now knows how to act, based on the present situation. Actions of Secondness are very useful when the agent does not have time for thinking, but previous experiences have created a set of rules relating specific situations to specific reactions. In this case, they might be proposed in order to repeat a behavior already performed in the past, which might have been proven useful. Instead of simply trying everything, like with the Actions of Firstness, Actions of Secondness might go straight to the point, regarding the current situation. But even though an agent might achieve interesting behaviors with just Actions of Firstness and Actions of Secondness, only with Actions of Thirdness an agent might really succeed in shaping the environment into a future desired state. The problem is that Actions of Thirdness might be very costly to propose. They require a good model for the effect of different actions, and might require elaborate planning strategies in order to move from the current present situation up to the desired future state. Also, if unexpected changes at the environment do appear, they might require some sort of re-planning in order to be successful.

Different strategies might be used to generate Actions of Firstness, Actions of Secondness and Actions of Thirdness. Boden (1998) introduces a very interesting typology of creativity that can be used to propose new actions. In her words:

“There are three main types of creativity, involving different ways of generating the novel ideas. The first type involves novel (improbable) combinations of familiar ideas. Let us call this ‘combinational’ creativity. Examples include much poetic imagery, and also analogy-wherein the two newly associated ideas share some inherent conceptual structure. [...] The second and third types are closely linked, and more similar to each other than either is to the first. They are ‘exploratory’ and ‘transformational’ creativity. The former involves the generation of novel ideas by the exploration of structured conceptual spaces. This often results in structures (‘ideas’) that are not only novel, but unexpected. [...] The latter involves the transformation of some (one or more) dimension of the space, so that new structures can be generated which could not have arisen before. The more fundamental the dimension concerned, and the more powerful the transformation, the more surprising the new ideas will be. These two forms of creativity shade into one another, since exploration of the space can include minimal ‘tweaking’ of fairly superficial constraints. The distinction between a tweak and a transform is to some extent a matter of judgement, but the more well-defined the space, the clearer this distinction can be.”

It is interesting to notice that Boden’s typology intrinsically follows Peirce’s ideas of Firstness, Secondness and Thirdness. Exploratory creativity is clearly an instance of Firstness, as it requires nothing to create a new one, using only the structure of the conceptual space. Transformational creativity is an instance of Secondness, as it requires a first in order to transform it and create a new one. And Combinational creativity is clearly a Thirdness, as it requires both a first and a second in order to create a new one. Assuming now that the conceptual space is the actuation space, each of the kinds of actions (of Firstness, of Secondness, and of Thirdness) can be created using either exploratory, or transformational, or combinatorial strategies.

Now, after possibly a set of actions was proposed (and among them, there might be Actions of Firstness, Actions of Secondness, and Actions of Thirdness), the agent needs to select one of them to be executed. Again, in the selection process, we might have three different strategies for action selection, based on Firstness, Secondness and Thirdness. The simpler selection strategy is a *non-deterministic* selection, a strategy using Firstness. This can be a completely random selection, or follow some statistical distribution, based on a set of priorities related to action selection. The main characteristic of the non-deterministic selection is that, following the same principle used in action proposal, the selection does not use the present state for making the choice, but just some fixed *a priori* set of preferences for doing so. The second selection strategy, now a strategy of Secondness, uses the present situation as parameter for choosing the action. In this case, the selection is some function of the present situation, the reason we are calling it the *deterministic* selection, as it is determined by the present situation. Finally, a strategy of Thirdness is the one that performs the choice using both the

present situation and a desired future state the agent is supposed to reach, which we are calling a *goal-based* selection.

After an action is finally chosen, it can be executed, by applying the chosen action parameters to the actuators.

6.2. Back to signals

Now, it's time to close the loop. At first, sensors capture and measure the signals coming from the world, allowing the agent to be aware of partial properties of the Dynamical Objects. The signals are transduced to a specific material substrate according to the nature of the agent, which maps the properties of the world into Qualisigns. According to the doctrine of signs of Charles Sanders Peirce, semiosis occurs through the growth of signs, from the most elementary of them, the Qualisigns, to the most developed, the Arguments. This process is not necessarily an infinite one, but it can also end on actions induced by Energetic Interpretants (connected to certain types of creativity). After a set of actions is proposed, one of them is selected, based on some algorithm of action selection, and finally, the action can be executed, by setting up the actuators with a determined set of signals, which might cause a possible change in the environment. This change upon the world makes the sensors capture new signals, making the whole process of cognition go on and again.

This loop is in accordance with Noe. To him, perceiving is a way of acting and perception is not something that happens to us, or in us, but something we do. And he claims that:

“To be a perceiver is to understand, implicitly, the effects of movement on sensory stimulation. [...] An object looms larger in the visual field as we approach it, and its profile deforms as we move about it. A sound grows louder as we move nearer to its source. Movements of the hand over the surface of an object give rise to shifting sensations. As perceivers we are masters of this sort of sensorimotor dependence. This mastery shows itself in the thoughtless automaticity with which we move our eyes, head and body in taking what is around us. [...] The central claim of what I call enactive approach is that our ability to perceive not only depends on, but is constituted by, our possession of this sort of sensorimotor knowledge.” (Noe, 2004, pp. 1–2)

The sensorimotor approach depends on two complementary instances of the whole process. First, it depends on a feedforward instance that will result in some immediate effect on reality, and, second, it depends on a feedback instance that changes the state of the process based on the effect caused by the first instance. A similar approach is being addressed by Hawkins (2004, 2021) since 2002. He developed a new type of artificial neural network, called Dynamic Sparse Network that is not only inspired by biolog-

ical features but also tries to reproduce the structure of the neocortex, resulting in the HTM technology (Hierarchical Temporal Memory).

The network model proposed by Hawkins is a structure of various cortical columns disposed side by side. These columns have two layers, the input layer, and the output layer. Each column is responsible to receive feedforward sensory input from a specific sensor, e.g., from each finger of a hand in a typical position of grabbing an object (See Figure 12). There is combined information on the input layer composed by the sensory input itself and the location from which this sensory input is collected, sensed by means of proprioceptive collateral sensors. This combined representation allows the capture of features at specific locations at the original object being sensed, providing collateral information, which is essential during sign interpretation. Also, the output layer receives feedforward inputs from the input layer, converging to stable patterns representing the object that the hand has grabbed, such that the object can be mapped in the agent's mind. There are two ways to reach this convergence in the second layer: 1. By integration over time as the sensor moves relative to the object; and 2. By modulatory lateral connections between columns that are simultaneously sensing different locations on the same object. Finally, feedback from the output layer to the input layer allows the input layer to predict what feature will be present after the next movement of the sensor (Hawkins et al., 2017).

Hawkins experiment provides an insightful evidence for what we have already proposed in figure 7: that the location (position/orientation) from which a sensed signal comes from is *fundamental* for a proper representation of the world by means of signs. It is only due to this collateral information that signs might act as indexes, realizing its full-fledged semiotic potential for representing the world.

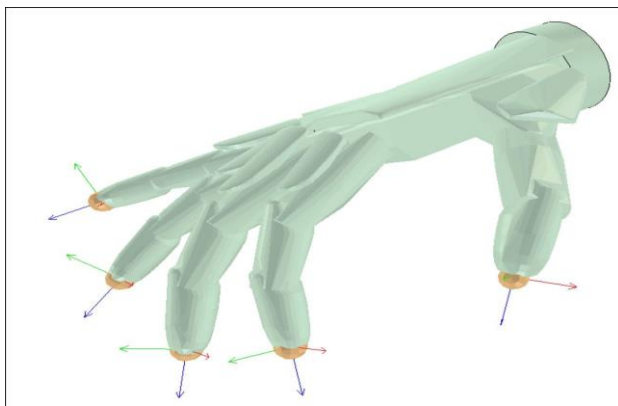


Figure 12: Hand in a grabbing position

7. SEMIOTICS OF ARTIFICIAL AGENTS

So far the analysis regarded a generic agent. Now we introduce some thoughts about the consequences of a semiotic approach to artificial agents based on digital technology such as a computer or a robot.

Each artificial agent must be programmed in such a way that a proper semiotic process can emerge, in order to build knowledge from data, allowing its use by the agent in the pursuit of its goals and purposes. Semiosis promotes the growth of signs, first from Qualisigns related to the World of Senses, towards Sinsigns and Legisigns related to the World of Things, and later to the World of Scenes. By creating a proper representation for the World of Existence, and abstracting the laws regulating it (forging a representation for the World of Laws), the agent is able to build a representation for the current situation, and with that explore alternative scenarios in the World of Possibilities such that possible courses of action leading to a desired future state might be planned. These dynamics make the system deal with increasingly developed signs, which the most developed of them are the Argument Symbolic Legisign, or simply the Argument.

Following Peirce's categories, an artificial agent is primarily in contact with the signs of Firstness, coming from its sensors, which provide hints about the actual state of the world, what can both be used to drive the agent actions immediately or to evolve more complex signs in memory, to be used in the future. What a sensor senses is different from what the sensor is, and, for an artificial agent, the signal set corresponding to the measurable properties of the world can only be transduced in numbers representing these properties. So, in the inner world of an artificial agent, all qualities of Firstness are numbers, and we assumed here that these numbers are in isomorphic relation to the entities of the world. Moreover, as the properties change in time according to natural laws the set of all measures obtained (numbers in relation to other numbers) also reflect an isomorphic relation, this time with laws, and laws as a generalization can be understood as concepts.

In the context of artificial agents, all concepts can be addressed as data that is used as a substrate for different kinds of signs, as time passes. The process of data flow can be represented by the ultimate techniques of artificial intelligence, such as neural networks, from conventional approaches of Deep Learning to the previous mentioned Dynamic Sparse Networks. No matter which kind of representation is picked, it must have the capacity to computationally model two kinds of laws: 1. The laws that, given a specific representation, can generate replicas of such representation; and 2. Laws that, given a possible replica, verify if it belongs to a general type, and, if so, to which law it corresponds.

So, as isomorphic structures induce the idea of iconicity, these numbers can be taken as icons of the existents, and, for this, the raw data collected by

sensors can be used to create a representational map of the world. But, in Firstness, the set of data is just a “background” of possibilities and some Firstness exploratory actions must be performed to find some coherent pattern that reflects an isomorphic structure to the world. This type of strategy is used in the field of artificial intelligence, mostly when techniques of neural networks and deep learning are used. Obviously, all process of constructing such architectures is mediated by human beings, and terms as “machine learning”, and even artificial intelligence can induce the wrong idea of genuine machine intelligence compared to human intelligence. But the essence of Firstness actions allowed by the background of raw data can be addressed to the artificial intelligence field, as it deals with possibility, probability, and, in some sense, with a non-deterministic approach, which is very useful in exploratory behavior. After an artificial intelligence model is developed, its use no longer implies possibilities, but conventional computation with deterministic relations between inputs and outputs, which points to Secondness, the domain of dyadic relations. If some aspects of artificial intelligence can be related to Firstness, and conventional computation to Secondness, Which aspects of the computational field could be addressed to Thirdness? E.g., is it possible to address artificial creativity? Returning to Boden, she claims that:

“Computer models of creativity include examples of all three types. As yet, those focused on the second (exploratory) type are the most successful. That’s not to say that exploratory creativity is easy to reproduce. On the contrary, it typically requires considerable domain-expertise and analytic power to define the conceptual space in the first place, and to specify procedures that enable its potential to be explored. But combinational and transformational creativity are even more elusive. The reasons for this, in brief, are the difficulty of approaching the richness of human associative memory, and the difficulty of identifying our values and of expressing them in computational form. The former difficulty bedevils attempts to simulate combinational creativity. The latter difficulty attends efforts directed at any type of creativity, but is especially problematic with respect to the third.” (Boden, 1998)

8. CONCLUSION

The difficulties pointed by Boden can be found in all attempts to create precise models of the mind that could be reproduced in a computational environment, including the ones inspired by biological entities such as the human brain. Lindsay (2021, pp. 360–364) points that even the most expensive models are not perfect replicas of the object of inspiration. Due to the great complexity involved, the creators of these models need to choose what to include and what must be left outside the model, in other words, what the scientists aim to explain and what they can ignore.

In order to face this challenge, this article tried to expose some principles of the General Theory of Signs developed by Charles Sanders Peirce that can address a new vision about how the minds possibly work. Bringing semiotics to the cognitive science field could be a very fruitful effort in the task of planning and building more efficient artificial agents. To do so, this work proposed a diagrammatic representation of signs, of semiosis, and of the relations between Qualisigns, Sinsigns, and Legisigns that can help researchers to find the essential informational process involved in the sensing-actuating loop that leads to the capacities of getting knowledge about the objects of the world and of actuating back changing these objects.

This interaction starts with the sensor devices that capture and measure signals from the environment, such that these signals must be encoded into signs: first into Qualisigns, and, as the semiotic process goes on, these signs grow in the direction of most developed signs, in order, from Qualisigns to Sinsigns, and from Sinsigns to Legisigns. Thus, semiosis is responsible for increasing the knowledge about the world. Finally, from the knowledge acquired, the agent can act upon the world, changing it and making new signs available. When considering an artificial agent, the implementation of the whole process can be possibly addressed through Dynamic Sparse Networks that conjugate feedforward and feedback treatment of the signals transduced by sensors.

At this moment, the semiotic approach proposed here represents the preliminary efforts in the direction of planning and building Semiotic Artificial Agents. We believe that this is the beginning of a very promising path of research.

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ABOUT THE AUTHORS:

Eduardo Camargo — PhD, Post-Doc Researcher, DCA-FEEC-UNICAMP, Av. Albert Einstein, 400 13083-852, Campinas, SP, Brasil.
Email: cepca- margo@gmail.com

Ricardo Gudwin — PhD, Professor, DCA-FEEC-UNICAMP, Av. Albert Einstein, 400 13083-852, Campinas, SP, Brasil.
Email: gudwin@unicamp.br