Revista Brasileira de Cartografia
ISSN 1808-0936 | https://doi.org/10.14393/revbrascartogr
Sociedade Brasileira de Cartografia, Geodésia, Fotogrametria e Sensoriamento Remoto

Remote Sensing as a Semiotic Game

Sensoriamento Remoto como Jogo Semiótico

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Received: 12.2022 | Accepted: 03.2023

Abstract: Based on the Remote Sensing metaphor as a semiotic game, this article aims to present a semiotic reading of the process of obtaining and interpreting products from sensor systems. For that, Charles Sanders Peirce's semiotic theory was used as a theoretical foundation, especially his discussions on the structure of the sign, the phenomenological categories and the relationships evidenced by the second trichotomy, namely: icons, indexes and symbols. The central argument is that the use of the game metaphor for the practice of Remote Sensing allows a more detailed look at this process, since the approaches of this practice tend to greatly value the discussions of the physical scope, played by electromagnetic radiation, but leave in a second plan the discussions about how the signs participate in the semiosis that allows the construction of knowledge from these registers. As a result, it became evident how the notion of sign can connect the physical/psychic dimensions of Remote Sensing, the semiotic limitations of these registers in the representation of the dynamic Object and the recurrence of heuristic strategies of imagistic, indexical and metaphorical relations in the transduction process of these products features.
Keywords: Charles Sanders Peirce. Sign. Semiosis. Satellite images.

Resumo: A partir da metáfora do Sensoriamento Remoto como jogo semiótico, este artigo tem como propósito apresentar uma leitura semiótica do processo de obtenção e interpretação dos produtos oriundos dos sistemas sensores. Para tanto, empregou-se a teoria semiótica de Charles Sanders Peirce como fundamento teórico, sobretudo suas discussões sobre a estrutura do signo, as categorias fenomenológicas e as relações evidenciadas pela segunda tricotomia, quais sejam: dos ícones, índices e símbolos. O argumento central é que o emprego da metáfora do jogo para a prática do Sensoriamento Remoto permite um olhar mais minucioso sobre este processo, pois as abordagens desta prática costumam valorizar sobremaneira as discussões do âmbito físico, protagonizado pela radiação eletromagnética, mas deixam em um segundo plano as discussões sobre como os signos participam da semiose que permite a construção de conhecimento a partir desses registros. Como resultado, evidenciou-se como a noção de signo pode conectar as dimensões física/psíquica do Sensoriamento Remoto, as limitações semióticas desses registros na representação do Objeto dinâmico e a recorrência das estratégias heurísticas das relações imagéticas, indiciais e metafóricas no processo de transdução das feições desses produtos.
Palavras-chave: Charles Sanders Peirce. Signo. Semiose. Imagens de satélite.

1 INTRODUCTION

In the Remote Sensing game, it is necessary to decipher the clues provided by nature using technical knowledge and creativity: nature provides the riddles, and the player tries to solve them. It is also always a collective game, even if the player is alone in his office. From the energy that leaves the targets to the cognitive response of the user of satellite images, in addition to electromagnetic radiation (REM), there is another fundamental, but little credited, element in geosciences and which is addressed in this text: the sign.

In the most recurrent definitions of Remote Sensing, electromagnetic energy is frequently mentioned, but not the work performed by the signs. For Jensen (2009, p. XIII, our emphasis), "*Remote Sensing is the art and science of obtaining information about an object* ***without being in direct physical contact with the object****".* Novo (2010) understands Remote Sensing as the joint use of sensors and other equipment for processing and transmitting data *"with the aim of studying events, phenomena and processes that occur on the surface of*

planet Earth ***from the recording and analysis of the interactions between electromagnetic radiation and the substances that compose it in its most diverse manifestations****"* (NOVO, 2010, p. 28, our emphasis). For Zanotta, Ferreira and Zortea (2019, p. 11), *"it is the practice of obtaining information about the Earth's surface through images acquired from space, using reflected or emitted electromagnetic radiation, in one or more regions of the electromagnetic spectrum".*

Undoubtedly, these definitions present the central aspects of remote sensing, as they emphasize the absence of direct physical contact with the target and the intellectual work of the user of these products in mentally reconstructing the object from the response of its electromagnetic radiation. In this article, it is proposed that this practice works as a kind of game: the user must reveal the characteristics of an object of study without necessarily having **direct** access to it.

It is the absence of this direct contact with the object that the term **remote** refers to. The adjective implies that the contact between the user and his target occurs in a mediated way: on one hand, the object's features are obtained from the electromagnetic radiation that interacts with it and is transmitted to the sensor. The sensor, whether on board in a drone or a satellite, will allow the transduction of the captured energy to another product, such as a digital image. This image, on the other hand, will be decoded by a mind that may or may not be human, responsible for interpreting the energy collected registered and processed during the survey. It is noticeable that there are numerous mediations established between the object and the human mind.

However, the entire universe is made of mediations: in the same way that the electromagnetic radiation radiated by the Sun is capable of triggering the process of photosynthesis in a plant without it being in direct contact with the source of energy, the star interacts with the organism alive, but to some extent. The rock, urged by the force of gravity and atmospheric weather, triggers its displacement to a lower point: the atmosphere, therefore, to a certain extent, comes into contact with the rock. The skin, when directly touching a surface, triggers a neurological response that will be processed by a mind and that serves, to a certain extent, as a mediator of the surface itself for a mind. By saying that, it is possible to state that each and every interaction that exists in the universe is permeated by mediations, that is, by signs. Hence the relevance of Semiotics, the science that studies signs and their transformation processes (SANTAELLA, 2004).

Considering the above, some questions about the Remote Sensing process are listed: how is the **physical** interaction of electromagnetic radiation with the target and the sensor transformed into a **psychic** interaction with the mind of the user of these products? If mediation is a feature common to all forms of human interaction with the world, what would be the specificity of the mediations provided by Remote Sensing products? How does the interaction of the physical dimension of electromagnetic energy with the psychic dimension of the user occur? This "break" between mind/matter is one of the riddles that can be studied by Semiotics. In the words of Abbagnano (2007):

> Although this word [riddle] is still used today for rhetorical purposes, it has become inappropriate for expressing the attitude of modern man in the face of limitations or the imperfection of his knowledge of the world. Riddle properly means "divination", and the expression riddle of the world seems to indicate that the world, like a gigantic guessing game, has only one solution which, once found, would eliminate all problems. Which, of course, is a rather puerile view, since the world has no enigma, neither in the plural nor in the singular, but only problems for which there are more or less adequate solutions, never definitive and always subject to revisions (ABBAGNANO, 2007, p. 396).

As Abbagnano (2007) points out, the riddle is not an attribute of the world, but of the reading of the world carried out by human beings. The "guesses" of the riddle can be more or less satisfactory, more or less elaborate, but not absolute, at least when it comes to scientific riddles. In addition to the passage of a physical/psychic dimension, another enigma that arises is about how the user of Remote Sensing products manages to guess the characteristics of their object of study.

The idea presented in this text considers that the two riddles have as a central element the concept of sign. In this sense, the main purpose of this text is to discuss how the transformation process of the signs obtained by capturing and processing electromagnetic radiation occurs, which happens in the physical sphere, with the information and knowledge generated by the user of these products about the target of study, that takes place in the psychological realm. It is proposed that this guessing game can be understood from the

semiotic discussions of Charles Sanders Peirce.

The purpose of these discussions is to contribute to making the Remote Sensing process more evident, which is sometimes "automated" by practice and technical applications. Analyzing this semiotic process thoroughly can allow teachers to become aware of the different challenges involved in teaching and learning this practice. For professionals who work directly with these products, a semiotic analysis of the process can contribute to improving the reflections built on the objects of study. To the students, to know the rules of this semiotic game a little better.

Therefore, in addition to the Introduction, the text is organized into the following sections: first, a literature review is carried out to present the theoretical-methodological instruments of Semiotics, with the aim of familiarizing the reader with the analytical resources of this text. Then, a phenomenological and semiotic reading of the products generated by Remote Sensing is carried out, listing the theoretical-methodological assumptions of Peirce's theory, especially the elements of the second trichotomy (icon, index and symbol). Subsequently, the principle of continuity of semiosis is presented as a nexus for the articulation between the object and its evidence collected by the sensor systems, as well as the transformation of these signs into knowledge by the user.

2 DEFINING THE GAME RULES

Contact with the world is always a mediated experience: when making a telephone call to someone far away to obtain information about their life, the cell phone serves as a mediating element. Likewise, when looking directly at a person in front of you, the information obtained by sight, such as the appearance of the interlocutor's face, the voice tone perceived by the auditory system or even its smell are mediated by electromagnetic waves, sounds and particles released from bodies (SANTAELLA, 2013). This means that every sensing practice is to a greater or lesser extent remote, as what is called direct contact would imply the possibility of performing cognitions without mediations, that is, without signs (CP 5.251; SANTAELLA, 2004).

According to the Michaelis dictionary (2022), the word **remote** is of Latin origin (remotus) and means something that is far away in space, distant. For Meneses (2012), this term was used together with **sensing** for the first time by Evelyn L. Pruit and her collaborators in 1960 to denote the process of obtaining information about a target, even through a vacuum, through electromagnetic radiation.

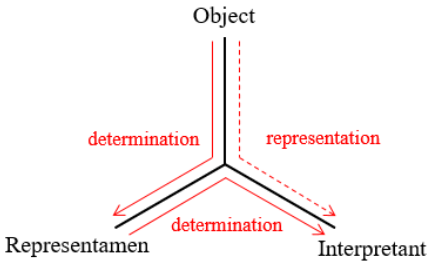
The elements responsible for making these bridges between the elements that make up the universe are called signs. The awareness of the existence of signs can be found at least since the Greeks, but their systematization as a modern science only occurs from the second half of the 19th century, especially with the contributions of the American logician, philosopher and mathematician Charles Sanders Peirce (1839-1914). In its semiotic conception, a sign can be defined as:

> anything which on the one hand is so **determined** by an **Object** and on the other hand so **determines** an idea in a person's mind, that this latter determination, which I term the **Interpretant** of the sign, is thereby mediately **determined** by that **Object**. A sign, therefore, has a **triadic relation** to its Object and to its Interpretant (CP 8.343, our emphasis).

Graphically, the relations expressed in the definition above can be represented according to Picture 1. It is emphasized that the tri-relativity of relations incorporated in the sign prevents its elements from being reduced to dyads (Object – Representamen; Representamen – Interpretant; Object – Interpretant), and the Object, which has ontological primacy in the sign, is represented by the Interpretant only in terms made possible by the Representamen. The meaning of determination and representation relationships is addressed in the following paragraphs of this text.

 DOI: http://dx.doi.org/10.14393/rbcv75n0a-67859

Picture 1 – Elements and relationships of the sign.



Source: Elaborated by the author (2022).

The terms used by Peirce in defining a sign are formal and abstract, as they were not designed to contemplate its constituent material, for example, but its logical function (SANTAELLA, 2004). This allows any element to play the role of a sign, material or immaterial, real or imaginary, without ceasing to be something else: a letter that carries a message remotely elaborated by someone is a sign, as well as the electromagnetic energy arising from it from a distant target. From this pansemiotic view, Peirce states that *"the whole universe is permeated with signs, if indeed it is not composed exclusively of signs"* (CP 5.448).

Regarding that, when adapting the formal definition of sign proposed by Peirce for Remote Sensing products, it can be said that:

> [it is an image] which on the one hand is so **determined** by an **Object** [the target] and on the other hand so **determines** an idea in a person's mind [the user of the images], that this latter determination, which I term the **Interpretant** of the sign, is thereby mediately **determined** by that **Object** [the target]. A sign, therefore, has a **triadic relation** to its Object and to its Interpretant (CP 8.343, our emphasis, our inclusion).

It is important to emphasize that the sign is not a thing, but a logical engendering between three entities: the Object, which determines the Representamen and this, in turn, determines the Interpretant (SANTAELLA, 1995). Mediatedly, the Object is represented by the Interpretant, but only in terms defined by the Representamen. Hence, there are two relations that constitute the sign: **determination** and **representation**.

To state that the Representamen is determined by the Object means to say that this element has a real primacy over that one, that is, that the Object exercises a predication over the Representamen (SANTAELLA, 1995). By predication, in logic, it is understood as "the act of joining a predicate to a subject of a proposition in order to increase the logical extension without decreasing the logical depth" (CP 2.359), that is, an operation that allows to derive object information. In the case of the representation relationship, the Object establishes an interaction with the Interpretant, but not in a dyadic way: it does so through the Mediation of the Representamen. For this reason, it incorporates into this dynamic the determinations that it exercises over the Representamen and this exercises over the Interpretant. When changing the Representamen of a sign, the determination of the Object is transformed and, consequently, the mediation with the Interpretant.

According to Pinto (1995), the Representamen is a technical term used by Peirce to designate anything that presents an unrealized potential for mediation. In the context of human cognition, the Representamen is the form that a sign can assume to be interpreted. A satellite image, for example, materializes the communication possibilities of the information it potentially carries about a target, but its Representamen does not depend on the fact that this sign can be found by someone or even interpreted correctly: for this reason the author states that every sign is composed of a Representamen, but not every Representamen is a sign (PINTO, 1995).

In the presented definition of a sign, the satellite image is "directly controlled" by the imaged target, which in this case plays the role of Object. The notion of determination comes from the force exerted by the sensed target, which literally marks the Representamen with its energy. Although the subject does not directly see the target, but its sign, it becomes mediately accessible through a representation.

Representation involves *"being in the place of, in other words, being in such a relation to another that, **for certain purposes**, is considered by some mind to be that other"* (CP 2.273, our emphasis). In Remote Sensing, the representation relationship is evident: it is not about having total and unrestricted ("direct") access

to the target, but to the electromagnetic energy patterns that derive from it and reach the sensors. These are the energy attributes of the target, but the entire imaged area contains characters that are only partially detected by the sensors. Thus, any and all Remote Sensing operations involve the collection and transformation of signs, which are, to a certain extent and for certain purposes, considered to be in the place of the targets.

The determination relationship between the Object and the Representamen is not biunivocal: even if electromagnetic radiation is the main element that controls the traits impregnated in sensor products, this relationship is mediated by this system, whose specificities can generate very different images: just imagine that two satellite images, even if they are obtained from the same scene, have very different communicative potential if they have different radiometric resolutions, for example. Furthermore, between the target and the sensor, the earth's atmosphere plays an important role in the behavior of electromagnetic radiation, reflecting, absorbing and refracting the radiant flux (JENSEN, 2009; NOVO, 2010). In this sense, this process reveals that the sign has at least two types of Object: the **immediate**, which is a limited and partial portion of the totality of the target, and the **dynamic**, which corresponds to all the characters of the imaged phenomenon and not just the features captured by sensor systems (SANTAELLA, 1995; SILVEIRA, 2007).

A sign does not necessarily need to have only one Object. In fact, multiplicity is the rule in the semiotic universe. In the case of products from Remote Sensing, the images contain the marks not only of the target, but of the imaging equipment itself, the time the procedure was performed (which affects the availability of energy captured from the scene), the altitude at which it is located in a certain orbital position, the coordinates of the location, among others, as Camargo and Gudwin (2022) point out. For this reason, the claim that the satellite image is "directly controlled" by the imaged target must be received sparingly. This fact makes it clear that the potential informative capacity of a sign does not reside entirely in the interpretative ability of the user, as it is an objective property of signs.

The relationship that exists between the sign and its Object does not occur in the same way in nature. A word, for example, stands in the place of an idea differently from smoke to fire; likewise the resemblance of a cloud to an animal occurs differently from the former case. As the diversity of signs involves phenomena of all kinds (physical, mental, dreamlike, chemical, energetic, etc.), Peirce's Semiotics demands the support of a quasi-science whose sole objective is to develop universal categories to identify the peculiarities of phenomena, which is called Phenomenology (or Phaneroscopy) (SANTAELLA, 2004 and 2013).

According to Peirce (CP 1.284), *"Phaneroscopy is the description of the phaneron; and by the phaneron I mean the total collective of all that is in any way or in any sense present to the mind, quite regardless of whether it corresponds to any real thing or not"*. Furthermore, according to the author, it should be understood that:

> [...] that what we have to do, as students of phenomenology, is simply to open our mental eyes and look well at the phenomenon and say what are the characteristics that are never wanting in it, whether that phenomenon be something that outward experience forces upon our attention, or whether it be the wildest of dreams, or whether it be the most abstract and general of the conclusions of science (CP 5.41).

Peircean phenomenology considers the existence of three major categories called firstness, secondness and thirdness:

> Category the First [Firstness] is the Idea of that which is such as it is regardless of anything else. That is to say, it is a **Quality** of Feeling. Category the Second [Secondness] is the Idea of that which is such as it is as being Second to some First, regardless of anything else, and in particular regardless of any Law, although it may conform to a law. That is to say, it is **Reaction** as an element of the Phenomenon. Category the Third [Thirdness] is the Idea of that which is such as it is as being a Third, or ***Medium***, between a Second and its First. That is to say, it is Representation as an element of the Phenomenon (CP 5.66, author's emphasis, our griffins)

Although the excerpt is concise, it synthesizes several implications in sign relations that are of interest to remote sensing. Firstly, it demonstrates that the phenomenological categories are universal and not particular, being simultaneously present in a given phenomenon: for this reason, the target to be sensed may have a predominance of secondness, but also allows a glimpse of firstness and thirdness.

Secondly, the excerpt shows that the target's attributes belong to the universe of firstness (of qualities), but these can only be perceived when incorporated into the universe of existence (secondness). The recognition or categorization of an attribute as a typical quality of a phenomenon involves the conformation of firstness and secondness to certain laws (thirdness). Therefore, without thirdness, there would be no recognition of patterns or habits in nature or in the signals captured by sensor systems; without secondness, there would be no tangibility of the sensed target; without firstness, there would be no information to be derived by the practice of Remote Sensing.

According to Peirce, there are three ways of determining the object in relation to the sign: the icon, the index and the symbol (CP 4.531). They involve the articulation of the sign in relation to its dynamic Object, varying according to the phenomenological predominance of the Representamen.

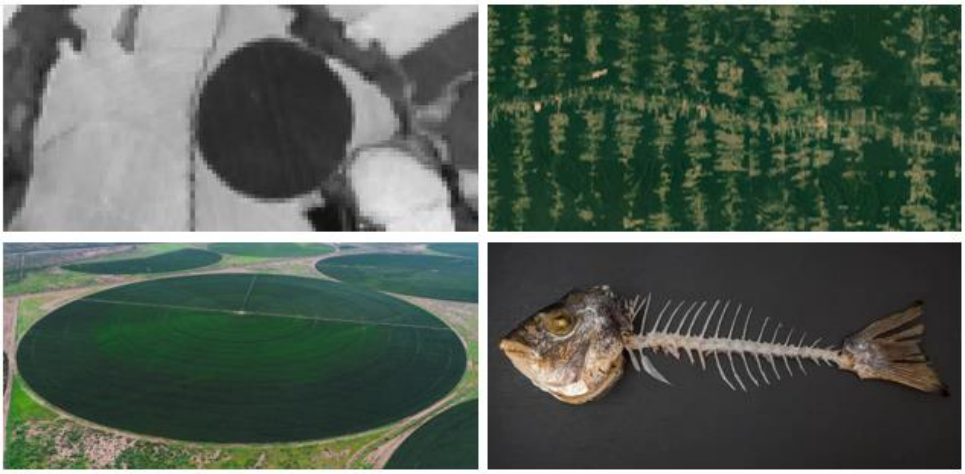
2.1 Icons and hypoicons in Remote Sensing

Icons and hypoicons are signs that have a relationship of similarity with their dynamic object(s). The difference between them occurs by the nature of the firstness in which they participate. For Peirce:

> 276. An Icon is a Representamen whose Representative Quality is its Firstness as First. That is, the quality he has qua thing makes him able to be a representamen. Thus anything is capable of a Substitute for whatever it resembles. [...].
> 277. Hypoicons may be roughly divided according to the mode of Firstness of which they partake. Those which partake of simple qualities, or First Firstnesses, are images; those which represent the relations, mainly dyadic, or so regarded, of the parts of one thing by analogous relations in their own parts, are diagrams; those which represent the representative character of a representamen by representing a parallelism in something else, are metaphors (CP 2.276-77).

Determination through an iconic relation occurs when the sign and the Object share some similarity of some quality (firstness). These qualities may be in form, structure, color, texture, or any other aspect of the phenomenon. In the case of an image produced by a remote sensor, the 'circular' shape of a plantation irrigated through a central pivot can fulfill this requirement, as well as the shades of gray that fill the geometric shape. Another example is the similarity between the deforestation pattern called “fishbone” and the vertebral column of this animal (Picture 2).

Picture 2 – Relationships of similarity between the signs and their objects.



Source: Elaborated by the author from the free collection of the site Pixabay.com and Google Earth Pro (2022).

The triadic relationship of the signs in Picture 2 can be attested by the fact that between the “shared” quality between the satellite image (the 'Representamen') and the target (its 'Object') must be constructed from an Interpretant. In this case, without a mind, be it human or not, to conjecture a similarity between the circular shape and the area with center pivot irrigation or even the deforestation pattern that “resembles” a fish bone, the sign would only be a potentiality to be performed, that is, it would only be a representamen. Therefore, this understanding can be extended to any Remote Sensing product: an aerial photograph, for example, registers

the attributes of a target and keeps a communicative potential that will be realized when a mind capable of its interpretation is activated.

Despite the realm of similarity of qualities being populated by the most diverse possibilities, like every phenomenon of the first phenomenological category, Peirce identified three main types of similarity relationships that a sign can have with its Object: these relationships are called image, diagram and metaphor. These three subclasses belong to the domain of **hypoicons**, as they already show traces of the category of secondness due to the fact that they are tangible and, therefore, participate in the universe of existing ones.

2.1.1 IMAGE, DIAGRAM AND METAPHOR IN REMOTE SENSING

The image is the first relationship of similarity and it is inserted within the domain of the first Peircean phenomenological category: firstness. According to Peirce, in addition to this category, the universe presents phenomena of secondness and thirdness, which are continuous and non-exclusive of all phenomena. According to Silveira (2007, p. 42, our emphasis), *"firstness, as its name indicates, is the first basis of all reality, being **presupposed** in existential confrontations, as well as in every continuum and in every generalization".*

All possibilities, qualities, originalities and spontaneities in the universe belong to firstness. Silveira (2007) points out that firstness is 'presupposed' in reality because its domain of qualities is (co)acted by the domain of the existence of secondness: the circular shape of a phenomenon present in an aerial photograph is part of the materialized form. Because it is realized in something, its aspect of firstness is suffocated by the secondness of existence. To exist is to react, and every phenomenon of empirical experience belongs to the domain of secondness. On the other hand, firstness subsists in secondness, because to be presupposed it needs a mean to happen. Although incorporated into secondness, firstness remains in the phenomenon, but it can only be perceived in a presupposed way from overcoming the constraints of secondness. According to Pinto (1995):

> In other words, an image mimics its object and proposes it through itself. This would be a simple referential process, that is, the sign pointed to a referent, which consists of presenting something **as if it were what it is**. In the image/object relationship, therefore, priority is given to identifying the material quality of the icon (its **foundation**) with the object's one. In this type of relationship, the object is the constant referent (PINTO, 1995, p. 26, emphasis added by the author).

The most recurrently valued priorities in the interpretation of Remote Sensing products are: tonality/color, texture, size, shape, shadow, height, pattern and location (FLORENZANO, 2011). Every satellite image can present these attributes, but the way they are realized in different secundities makes each product particular.

For this reason, the attribute "circular" (firstness), which is used as a sign of the cultivated area irrigated by a central pivot, is not an exclusive attribute only of aerial photography, but of several everyday objects, such as a disk or a dish, for example. And even though there are several 'circular' objects, this attribute can trigger completely different interpretants, because they are found in different signs of existence (sinsigns). In Remote Sensing images, the circular shape provides an important clue to decipher which is the sighted target, but in a highly subjective way and strongly dependent on the context and the user's ability to make a correct guess. The only way for the user to prove if his hypothesis is true is through the search for index signs, which point to facts that really exist in the universe: this is a fundamental movement in the game of Remote Sensing.

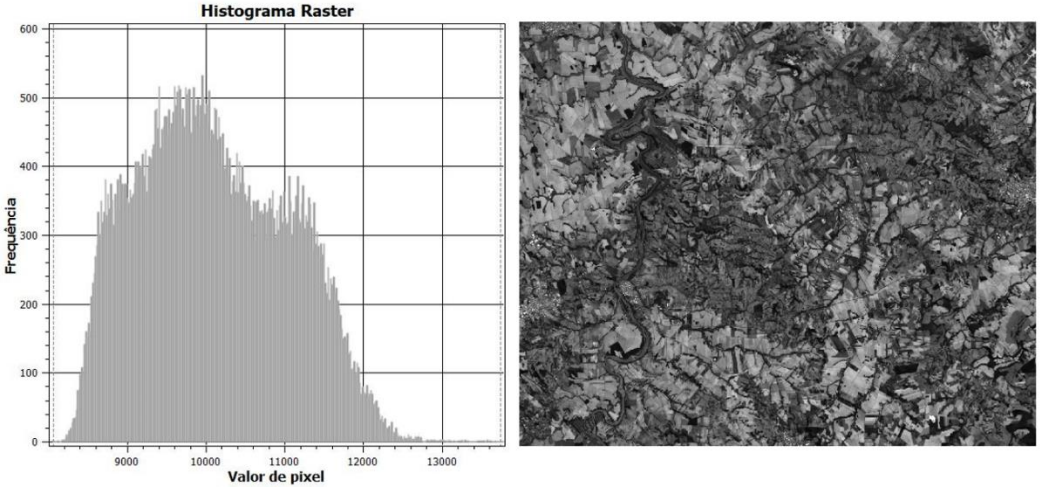
In addition to appearance, a sign can resemble its object by sharing a similarity of structure. According to Santaella (1995, p. 157), *"the diagrams, on one hand, represent by similarity in the internal relations between sign and object. It is no longer appearance that is at stake here, but the internal relations of something that resemble the internal relations of something else".*

All types of graphs are considered diagrams, as they are related to their phenomena, but their appearance in no way resembles their respective Objects. A graph on the evolution of people infected by Covid-19 is in no way similar in appearance to infected people, but structurally it is compatible with their quantity. The topographic map, for example, is made up of several of these diagrammatic relationships, starting with the layout of the level curves: the isoypses only represent the structure of the relief, but in no way resemble a

 DOI: http://dx.doi.org/10.14393/rbcv75n0a-67859

mountain or a valley, for example (GARBIN and SANTIL, 2020). Likewise, the histogram of a satellite image resembles it only at the structural level, but not at the appearance level (Picture 3).

Picture 3 – The histogram presents a diagrammatic relationship with your satellite image.

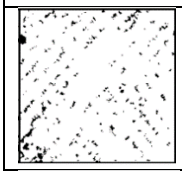
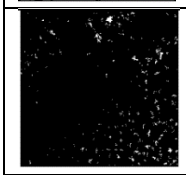
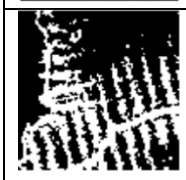
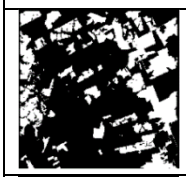
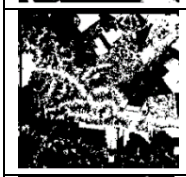
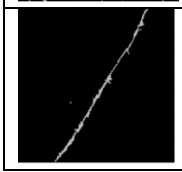


Source: Elaborated by the author (2022) from NASA (2022).

Although the structure of the phenomena is the main element in the constitution of diagrams, this does not mean that diagrams cannot also share the attributes of imagery icons. As Santaella (2005) reminds us, the combination and mixture of signs is a general rule in the semiotic universe, with pure classes only present in the analytical formulation of semiotic theory. In Picture 2, for example, the structure of the fishbone presents topological connections similar to the pattern of deforestation, namely: the irradiation of small filaments from a central line. This is a structural similarity. But the formal quality of these filaments is also similar in appearance: therefore, it is also an imagery relationship.

There are several diagrams used for the photointerpretation of satellite images. Saito et al. (2011), for example, present some of the deforestation patterns, as well as their more regular meanings in the context of the legal Amazon, as shown in Chart 1.

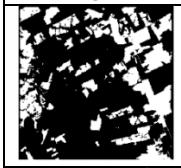
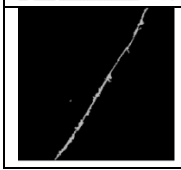
Chart 1 – Typology of diagrams of deforestation patterns present in the legal Amazon from the constituent elements of the sign on a scale of 1:100,000 (white = deforestation, black = forest).

Sign	Object (deforestation structure)	Representamen (form of deforestation)	Interpretant (deforestation outcome)
	Consolidated	Large and continuous patches of deforestation; varied form; low density and small areas of forest remnants; compact spots.	Land concentration; small, medium and large agricultural establishments; forest depletion; forest fragmentation; advanced stage of occupation.
	Diffuse	Small, isolated spots; varied shape, irregular shape; low to medium density; uniform distribution.	Areas of spontaneous occupation; small rural producers; agriculture, livestock and extractivism for subsistence; initial stage of occupation.
	Fishbone	Large, elongated, linear patches with ramifications similar to fish vertebrae; medium density.	INCRA's (National Institute of Colonization and Agrarian Reform) rural settlement project area; small and medium rural establishments; intermediate stage of occupation.
	Regular geometric	Medium to large and isolated spots; regular geometric shape; low to medium density.	Medium and large rural establishments; medium to large scale agricultural activities; intermediate stage of occupation.
	Messy multidirectional	Small, medium and large spots; stains of varied, irregular shapes, high complexity; medium, high density; multidirectional.	There may be land concentration; small, medium and large rural establishments; intermediate stage of occupation directed towards expansion, often spontaneous.
	Linear unidirectional	Medium and large spots; elongated spots arranged along hydrography or access roads; low density.	Riverside occupation; occupation along roads and access roads; small and medium rural establishments; initial to intermediate stage of occupancy.

Source: Saito et al. (2011) (adapted).

As the structure is the enabling element in the construction of similarities and not exactly the appearance of the phenomenon, these structures can be visualized in signs whose visible attributes are different. Evidently, as they share a structural similarity, imagery similarity can also occur, but this is not the central element in defining the diagrams, as exemplified by means of Chart 2. It is important to emphasize that the recurrence of certain diagrams as a pattern of a phenomenon brings the sign closer to thirdness.

Chart 2 – Recurrence of the structure of the diagrams in imagetically distinct occurrences at a scale of 1:100,000 (white = deforestation, black = forest).

Signo	Padrão de desmatamento	Exemplo 1	Exemplo 2	Exemplo 3
	Regular geometric			
	Linear unidirectional			

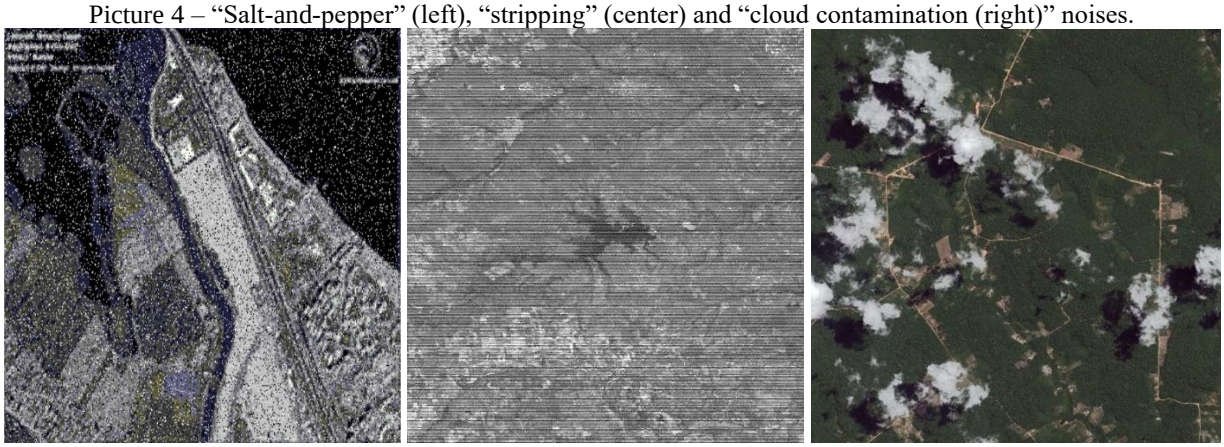
Source: Prepared by the author (2022) from Saito et al. (2011) and Google Earth Pro (2022).

The third relationship of similarity that can occur between the sign and its object is called metaphor by Peirce (2012) and constitutes a relationship of parallelism between the sign and something else. According to Santaella (1995, p. 157), *"they only extract the character, the representative potential in terms of quality, of something and make a parallel with something different. There is always a strong dose of mentalization and activation of meanings in metaphors, hence they are hypoicons of thirdness".*

The role of metaphors for human cognition of the world is recurrent and manifests itself in the most diverse situations, which is the object of study by Lakoff and Johnson (2003). For the authors, metaphors can demonstrate their heuristic role from the most varied examples: when considering a debate as a 'war' of arguments, metaphors allow one to state that certain ideas are 'indefensible', that the interlocutor went 'straight to the target' or that the arguments were completely 'destroyed' (LAKOFF and JOHNSON, 2003). By establishing a parallelism between arguing and fighting, it is possible to extend the connotative dimension that linguistic signs originally presented.

It is for this reason that it is often said that a person has a "peach skin", that the weather is "grim" or that "the sea is not for fish". In Remote Sensing, metaphors also play a strategic heuristic role, as can be expressed through the *"salt-and-pepper"* effect, which is a noise *"characterized by small polygons spread throughout the mapped area and that end up demanding post-processing operations, such as filtering, for their elimination"* (BRITES, BIAS and ROSA, 2012, p. 209), "stripping" noise, or even when it is stated that an area it is 'contaminated' by clouds, as illustrated in Picture 4. The metaphor is used to indicate that the image appears to have been "seasoned" with grains of salt and pepper, that it is being "peeled" or that the area of interest is not "clean", and help in detecting noises that require pre- or post-processing operations.

Picture 4 – "Salt-and-pepper" (left), "stripping" (center) and "cloud contamination (right)" noises.



Source: Kolhe and Jain (2013, p. 2055) and USGS (2022).

The very title of this text, which establishes the parallelism between the practice of Remote Sensing as a semiotic game, allows structuring a semiotic argument in such a way as to facilitate a new concatenation of ideas to explore new aspects of this practice. In this sense, the semiotic game of Remote Sensing requires the elaboration of different semioses to solve the enigma of the signs present in these products. The key to solving this mystery involves the abilities to find similarities between the sign and its dynamic Object, which are always partially revealed. This dynamic Object, as already mentioned, is reality itself in all its dimensions, and can be explored at the level of appearance (firstness, image), structure (secondness, diagram) or parallelism through a mental action (thirdness, metaphor).

2.2 The indexes in Remote Sensing

If the satellite image corresponds to the sign and its referent to the Dynamic Object, and the perceived similarity relation always has a hypothetical character, it is worth clarifying the mechanisms that the user resorts to guarantee that these perceived iconic relations correspond, in fact, to a true characteristic of the object and not to a false conjecture. It is here that the need for the collection of indexical signs appears.

Unlike hypoicons, which depend on a mind to build a relationship of similarity between the sign and the Object, the relationship established by the indices does not occur this way: the index is factually affected

by its object (SANTAELLA, 1995). Also according to the author:

> Wherever there is a real, dynamic connection, however rudimentary it may be, there will be a trace of indexicality [...]. Of course, it will only function as a sign when it finds an interpreter, but it is not the interpreter that gives it that power, but its **affection** with that object. When the index is genuine, really dual, the role of the interpreter is **only noting the mark**, in the sign, of its affection for the object (SANTAELLA, 1995, p. 160, our emphasis).

The indexes are the ones that allow the connection of an image resulting from Remote Sensing with a particular target. According to Peirce, the indexes point to individual and existence phenomena, that is, of secondness (CP 2.283). For example: the circular shape of a center pivot irrigated area is fixed by the sensor because the area, which is circular, actually affects the sensor; if the shape of the irrigated area were square, the image produced would acquire a corresponding shape.

It is noticed that the quality (firstness) of the form remains in the sign, but the reason why the fixed form is this and not that does not depend on the ability of a user to perceive or agree with this similarity. Therefore, the index highlights the dual connection between the sign and its object, leaving the interpretant "only" the task of perceiving this fact, with the cost of, if it fails in this task, ultimately putting its own survival at risk:

> The survival of all species, and of each individual member of all species, depends on the correct deciphering of indexical signs [...]. The trail-followers of horses or other animals, the prophet and soothsayer, the detective, the art historian, the physician, the psychoanalyst and modern scientists are, each in their own way, readers and interpreters of natural metonymies in the Book of Nature. Nature – in the same way that we experience signs in our everyday life, although perhaps in a less concentrated and less specialized way (SEBEOK, 1991, p. 49 apud SANTAELLA, 1995, p. 157-8).

This occurs because the indexes marked on Remote Sensing images are factual, in other words, the digital image is genuinely affected by the Object (CP 2.283), but this genuine relationship only occurs at the instant of image formation. When transmitted to a data processing center or even printed, the satellite image loses its real connection with the target, becoming only referential, that is, it becomes a degenerate index.

It can be said that it is the correct decipherment of the position of the celestial bodies that allowed the human being to orientate himself in space, as well as the correct decipherment of the energy patterns captured by the remote sensors that allows the user to know the Object, even remotely. If the image that portrays a target is not the target itself, but an indexical sign (genuine or degenerate) that points to it, then this sign must present or it has already presented a real connection with its dynamic Object, in such a way that this contact has marked (modified) the sign, like a footprint in the sand in relation to the foot, for example. When in contact with the Representamen, the Object also transfers part of its characters, making the sign potentially able to communicate the Object's qualities.

In the case of Remote Sensing images, the means used to leave this mark of the object on the sign is electromagnetic radiation (REM) (JENSEN, 2009; NOVO, 2010). Therefore, it is not the target itself that is **directly** sensed, but the REM that leaves a given body and, when colliding with the sensor positioned on a satellite, transmits to the sensor a specific amount of energy produced by the target in question. There is a physical connection between the sign and the object, which are electromagnetic waves and photons: the theory constructed by the user about the relationship between energy and the body is a conjecture, but the relationship between energy and the body are material facts (MONTEIRO, 2018).

Although the distance between a user of Remote Sensing products inside his office and the target is relatively large, making it impossible to verify the phenomenon 'directly', in everyday life the process of deciphering the indexes that permeate the routine are also the result of conjectures hypothetical reasoning. When looking, at this moment, at the screen of the electronic device or at the paper that is a few tens of centimeters away, the mechanism of transmission, reception and decoding of the indexes occurs in a mediated way.

Perhaps, at the limit, it can be said that all interaction between the human mind and the universe occurs remotely, because energetic connections, even if they occur at subatomic levels, mediate our contact with the

world, and human minds are constantly deciphering these enigmas (SANTAELLA, 1998).

3 REMOTE SENSING AS A COLLECTIVE GAME

Although the activity of interpreting a satellite image can be carried out based on individual action, the Remote Sensing game is always collective, as well as any scientific activity. According to Peirce (2008), all investigation stems from the human need to overcome a state of doubt and reach a state of belief. In general terms, in the state of belief there is the security of certainties about the issues that are imposed on life, but from the moment that a doubt escapes previous beliefs, a very uncomfortable state of lack of security is established to make the appropriate decisions and that is called a state of doubt.

There are several levels of doubts that human beings face: from uncertainty about the possibility of raining to bring a waterproof cover to work, to uncertainty about the increase or decrease in deforestation in a study area. The effort to overcome the state of doubt and the arrival at a state of belief, Peirce called investigation (PEIRCE, 2008).

Scientific research is made up of important differentials in relation to other forms of knowledge construction. According to Peirce (2008), the method of science considers that there is an external reality, which should not be restricted to the individual, that is, a reality that can be attested by a collectivity, ensuring that anyone finds the same results, if properly follows the analysis procedures. Furthermore, the results obtained in this search *"must be public and submitted to the criticism of the other"* (SANTAELLA, 2004b, p. 73), enabling the progress of science and the search for truth (always of a temporary nature) in a constant construction.

The temporary character of the knowledge generated by research and its need to be under constant review by a community of researchers does not mean that the truth or falsehood is a matter of cultural agreement or historical convenience, but that there is a state of affairs that insists on its condition and that the long human walk should try its best to get closer (SANTAELLA, 2004b). In practice, this means that in a hypothetical situation of two users of the same satellite image that present absolutely discordant conclusions, one of them will have their hypothesis radically corrected when put to the test by a community of researchers, since the scientific method presupposes the existence of an external reality, which is not a mere product of human subjectivity (SANTAELLA, 2004b). It is for this reason that indexes are fundamental to point out reality in the process of scientific investigation.

The communication process between investigators of a scientific community that re-examines the results obtained by the research is made possible by sharing a common foundation that unites the minds of the interlocutors, called commens by Peirce: *"a collective, continuous mentality, resulting from the minds involved in communication"* (ROMANINI, 2016, p. 27). The construction of a common foundation for researchers is the result of the generalization of individual sensations and observations, which creates a culture (ROMANINI, 2016). It can be said that users who are specialists in the interpretation of products from Remote Sensing share the same culture, impregnated with concepts, ideas, beliefs, that is, signs of thirdness, which are not restricted to the individual's knowledge, but which grows and generalizes collectively (GARBIN, 2020).

A sign that is general and not particular belongs to the phenomenological universe of thirdness (SANTAELLA, 1995; SILVEIRA, 2007), receiving the denomination of symbol. *It "is a sign which refers to the object it denotes by virtue of a law, usually an association of general ideas, which operates to cause the symbol to be interpreted as referring to that object"* (CP 2.249). Without the symbol, there would be no possibility of learning Remote Sensing techniques. Symbols can be classified as resulting or not from a convention, understood as *"the semiotic relations established by a human community between a sign and what it conveys, without the sign and its object being linked in any other way than by this convention"* (SCHAEFFER, 1996 apud SANTAELLA, 2013, p. 241).

3.1 Conventional Symbols in Remote Sensing

Satellite images are not trivial products and require specific preparation for the user to be able to decipher them. Evidently, by presenting imagery relationships, non-specialist users can conjecture similarities

between the sighted form and a type of target already known (Picture 2), but more sophisticated mental operations (Chart 1) require knowledge about the functioning and characteristics of the sensors , the behavior and interaction of REM, among others.

During their training process, the users will come into contact with the most diverse concepts, examples, classes and experiences in order to internalize a certain state of minimum scientific knowledge that enables the use of sensor system products (GARBIN, 2020). It is the generality of processes apprehended, exercised and internalized by the student that will incorporate him into a culture - the culture of specialists in Remote Sensing -, which provides the necessary code to unravel the enigmas of nature encoded by sensor systems.

According to Merrell (2012, p. 146*), "a symbol like the word "train" does not evidence any particular connection with "trains" in general or with any "train" in particular, unless there is a connection established by a another semiotic agent, that is, unless the connection is made by the mind"*. Likewise, the existing relationship between the gray levels of an image in a given band is only recognized as an effective Interpretant if the user of these products knows a sufficient set of symbols that conventionally synthesize this state of knowledge.

When Jensen (2009) and Novo (2010), for example, present the possible forms of interaction between REM and matter, expressing the concepts of absorption, reflection and scattering, they are contributing to the process of learning the symbols needed to interpret an image from satellite. In this sense, the formation of a conventionalized symbol assumes a dynamic similar to the enrichment of the user's technical lexicon, which does not invent new terms, but shares with the other members of the community a repertoire that allows communication between peers.

It is worth noting that precisely due to the typical condition of thirdness, no set of icons or indexes can exhaust or be equivalent to the general character of the laws or habits that are the characters of symbols, since *"the symbol does not denote a particular thing, but a type of thing, just as the interpretant of a symbolic legisign is not exhausted in the dynamic situation of the occurrence of one of its replicas"* (SANTAELLA, 1995, p. 178). Therefore, the consequences generated by symbols are formal and not material. According to Peirce:

> Any ordinary word, as "give," "bird," "marriage," is an example of a symbol. It is applicable to whatever may be found to realize the idea connected with the word; it does not, in itself, identify those things. It does not show us a bird, nor enact before our eyes a giving or a marriage, but supposes that we are able to imagine those things, and have associated the word with them (CP 2.298).

The symbolic relationship becomes evident when considering the generalized patterns of deforestation and their respective meanings, as expressed in Chart 1. It is the symbol that, by incorporating a diagram that represents a pattern of a process, allows, for example, the recognition of the traits in common in the examples in Chart 2.

3.2 Unconventional Symbols in Remote Sensing

In the Remote Sensing game, symbols are not restricted to conventionalized habits in the interpretation of satellite images, but to behavior patterns, whether of human semiotic agents or of the laws of nature. Therefore, if conventional symbols require the user to learn a code to decipher them, non-conventional symbols are independent of the individual's ability to make judgments.

This happens because, according to Peirce (CP 5.93), thirdness exists and is operative in nature. It is the existence of general laws and certain repeated habits of behavior in the universe that allows, for example, to affirm that a stone placed in a place with no obstacle between it and the floor, when released, will fall to the floor. But how can you know that? Peirce replies:

> It is clear that clairvoyance does not enter into the case [...]. I know that the stone will fall if I let it, **because experience has convinced me that objects similar to it always fall** [...]. But the general proposition that all solid bodies fall in the absence of force or pressure is a

formula of a representative nature (CP 5.94-97, our emphasis).

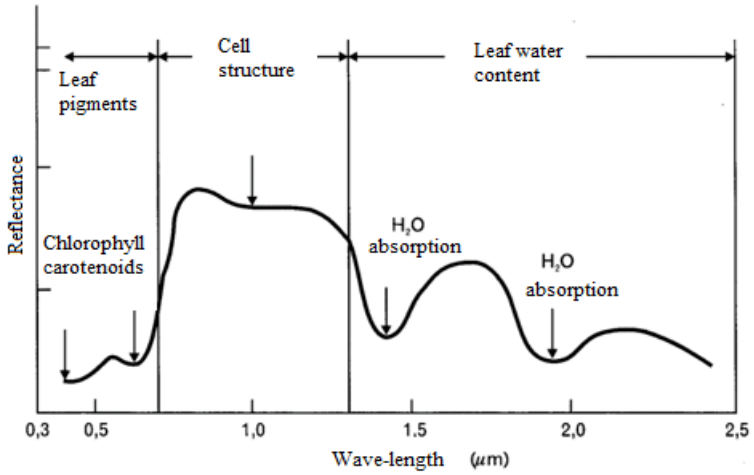
The law of gravity, therefore, presents a nature of thirdness: it governs the action of objects left without a shield, which allows guessing what will happen to other objects that are in the same circumstance.

In Remote Sensing, the imperfect regularity of nature's behavior expressed by non-conventional symbols is what allows the recognition of the usual spectral response of targets. These nature symbols are introjected not only in the minds of users, but in the very functioning of sensor systems. As Novo (2010, p. 242) points out, these regularities influence *"the very definition of new sensors, the definition of the type of pre-processing to which the raw data must be submitted or even the definition of the form of data acquisition"*.

As for the role of natural symbols for human cognitions, the usual behavior of the spectral response of targets is a necessary condition for a given target to be identified. For Novo (2010, p. 243), *"theoretically, if the reflectance of an object could be measured in adjacent and narrow spectral bands along the reflective region of the spectrum, a representative graph of its spectral signature could be constructed"*.

The graph mentioned by the author generalizes the structure of the average spectral behavior of a leaf, which can be used to build similarities between its spectral response with the one from the target in question (Picture 5).

Figure 5 – Spectral signature (average) of the green leaf.



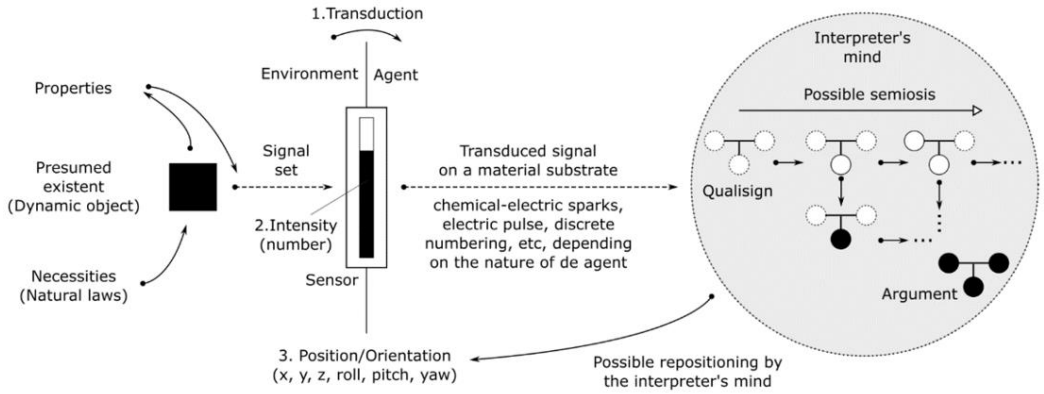
Source: IBGE (2001, p. 36).

As shown in the previous sections, the sign in Picture 5 presents a mixture of hypoicons, indexes and symbols. The hypoicons are of the diagrammatic type, because they present a similarity in the structural level of the radiation reflected by means of a graphic. The indexes are of a degenerate nature, as the graph was constructed from the factual response of electromagnetic radiation measured by a spectroradiometer, for example. With regard to the symbolic nature, the conventional and non-conventional nature of the sign can be seen: the first, because the definition of the axes of the Cartesian plane (x = wavelength; y = reflectance) is a pattern of this type of graphic; as for the non-conventional nature, it presents itself in the usual REM response of the pigments, structure and water content of the vegetable leaf that will serve as a generalizing element of the experience.

4 THE FIRST ROUND

Even though knowledge of the different stages of the Remote Sensing semiotic game allows players to get a sense of how the games work, this game must be understood panoramically, as shown in Picture 6.

Picture 6 – Diagram of the elements that participate in the Remote Sensing semiosis.



Source: Adapted from Camargo e Gudwin (2022) by the author (2022).

Picture 6 presents the semiotic relations discussed so far: the imaged target assumes the logical position of the dynamic Object, as it participates in the universe of tangible phenomena, that is, of secondness. This secondness comprises a series of properties that predicate it: spatial forms, size, texture of the ground cover, shading, height, among other attributes that are typical of firstness. The natural and anthropic processes that interfere with the conformity of the target's characteristics, as they are of the nature of thirdness, allow the recognition of behavior patterns of the elements of the scene. Therefore, it is noted that the phenomenological categories operate simultaneously and their separation is just an analytical resource to visualize the engendering of semiosis.

The first leap evidenced by Picture 6 in the semiosis of Remote Sensing is the transduction of the target's energy (which occurs in the physical scope of the environment) to another material substrate (also physical) that will represent the dynamic Object, either by means of a electrical pulse, or by means of a digital image. The term transduction chosen by Camargo and Gudwin (2022), in a stricter sense, is used in Biology to indicate the “transfer of genetic material between bacteria, through a virus that multiplies inside microorganisms” (MICHAELIS, 2022, s.p.) and in engineering as the process of converting a signal “from one physical form to a corresponding signal having a different physical form. Therefore, it is an energy converter” (PALLÀS-ARENY and WEBSTER, 2001, p. 2). It is curious to note that both in the context of Biology and in engineering there is a determination of an entity (the virus or energy - the Object) for a 'sign vehicle' (the bacterium or the converted signal - the Representamen). It is, therefore, a transduction of an Object (the target) to a Representamen (the signal generated by capturing the electromagnetic radiation of the Object) through a determination relation.

The second relationship of determination present in Picture 6 is situated in the transduction of the Representamen into an Interpretant, which in the context of Remote Sensing occurs in the passage from the physical to the psychic realm. The possible semioses are diverse, depending on the user's repertoire and cognitive ability to play with the clues encrypted by nature and by the processing of electrical signals recorded by the sensor systems.

If the player has in his repertoire the knowledge of the existing patterns in these products that indicate the circumstances of the image, he will be able to bet ("abduct") in the direction of the flight, in the pitch angle, in the rotation or even in the drift of the aircraft, in its angle of depression, among other attributes collaterally recorded by the sensor during imaging and which can also be accessed collaterally by the user. These attributes of firstness can be used to form hypoicons that may hypothetically refer to the dynamic Object, in an inverse movement to previous transductions, that is, from the psychic to the physical realm.

5 FINAL CONSIDERATIONS

When considering the Remote Sensing metaphor as a semiotic game, it is possible to highlight the pertinence of the sign concept in this process and the challenges involved in the construction of knowledge from products derived from sensor systems. Satellite images participate in this semiosis as a sign and as representamen: they achieve a possibility of being, to a certain extent, in the target's place for a certain mind.

The mediating element is the REM that is reflected by the target, which literally marks the remote sensor and allows it to create genuine and/or degenerate indexes of the target to be studied. The sign, based on the law of continuity between the physical and psychic universe, is absorbed by a mind able to recognize relations of similarity in appearance, structure or parallelism with something different.

Appearance similarity relations are typical of images, which allow the user to associate the sign with the Dynamic Object, but only in a hypothetical way. In Remote Sensing, similarity relationships derive from hue/color, texture, size, shape, shade, height, pattern and location of targets. The gray levels, the histogram or even the digital numbers that structure these products also allow the search for structural similarities through diagrams. Metaphors, in turn, serve to expand the domain of meaning of the sign from a strictly mental comparison. The elements that allow the use of the satellite image as a substitute for an area must be somehow linked to them, resulting in indexical signs.

Although the energy signature of targets is a phenomenon of nature, Remote Sensing specialists need training to allow these patterns to be deciphered. Therefore, on one hand, there are non-conventional symbols (of nature) and, on the other hand, conventional symbols. These conventional symbols allow the research community to dialogue and appropriate a certain state of scientific knowledge: hence the reason for saying that the Remote Sensing game is always collective.

Despite the fact that the rules are established through technical knowledge, the success of the match depends on the creativity of the players in generating broad reasoning. Let the games begin!

Authors contribution

The author was responsible for the research, conceptualization, writing, revision and final editing.

Conflicts of interest

The author informs that there are no conflicts of interest.

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 DOI: http://dx.doi.org/10.14393/rbcv75n0a-67859

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