
I-CONS: ARTIFICIAL SYMBOLIC VOCABULARY TO ENABLE EFFECTIVE SEMANTIC INTERPRETATION OF SHARED INFORMATION

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ABSTRACT

In engineering design processes, participants (architects and builders) depend on sharing information practices to communicate meanings through artifacts (3D visual representations). However, there are multiple instances of ambiguities and inconsistencies in these artifacts that produce workflow disruptions. For example in design review engineering activities, while some participants assume that others will have full familiarity with the artifacts (familiarity with some instances from the designs), other participants do not recognize some aspects of what a particular representation implies (some aspects of the artifacts are invisible to other project participants).

The observer's perception is a reaction towards some aspects of the artifacts but not necessarily the understanding of their intended meaning, such as design instances conditions in context. Therefore, the observer's awareness and ability to sensorially experience some aspects of designs, including symmetries, geometries, patterns, and connections, cannot be explicitly determined. The current mediation technologies (CAD systems, Parametric Models) enhance the designers' ability to manipulate data and observe information related to the designs. But they are not built to assert intended interpretations or to arrive effectively at implied conclusions.

Building on Semiotics this research explores the cognitive agents' (design interpreters) ability to efficiently arrive at less ambiguous interpretation of artifacts' meanings in sharing information practices. The challenge is to enhance the observer's experiences as they are directed towards some aspects of the artifacts by virtue of meaning and sensory-enabling-conditions. The focus is on improving cognitive agents' reasoning-efficiency-ability through the use of mediating technologies.

This investigation proposes intelligent geometric topologies for semantic interpretation of design components (iCon) to streamline the communication of designs. iCon is an artificial language that uses symbolic vocabulary based on a semiotic framework. It has extensions for basic operations that indicate actions (e.g. process, read) and for meanings to support intentionality (e.g., definition of interactions of two objects).

Keywords: semiotics, knowledge practices, knowledge management

1. INTRODUCTION

Proposed by Peirce (1991), the triadic relationship representation-agent-purpose is a fundamental semiotic categorization for the analysis of knowledge. This investigation builds on this fundamental relation to introduce the intelligent geometric topologies for semantic interpretation of building components (iCon). This research based granularity notion and the cognitive agent's reasoning to begin the analysis and understanding of the fundamentals of the semiotic framework, since there is a strong relation between semantics and the 'grain' size for the interpretation and the reasoning of the representations of building components (Mutis 2007b, Mutis and Issa 2008).

The observer's awareness and ability to sensorially experience components of building designs, including symmetries, geometries, patterns, and connections, cannot be explicitly determined. The observer's perception implies a reaction towards the components but not necessarily an understanding of their conditions and context. The challenge is to enhance the observer's experiences as they are directed towards the building component, by

virtue of meaning and sensory-enabling-conditions, to improve reasoning efficiency and reduce ambiguity. Limitations of any perceptual organs and mediation technologies reduce the observers' ability to assert interpretations or to arrive effectively at conclusion.

ICons are the result of knowledge engineering analysis aimed to enable efficient reasoning for project stakeholders' interpretations on geometric visualizations (e.g., BIM components, virtual 3D representations). Although, icon is a vocabulary composed of a set of imagery abstractions for symbol manipulation, they are built on logic to be computable. This logic is based on qualitative spatial reasoning (Cohn and Renz 2008, Freksa 1991) and on formalizations with Region Connection Calculus (Randell, et al. 1992). To secure consistency of the iCon's images, their primitives (e.g., relationship boundary interior) are built by borrowing formalisms from mereotopology theory (Smith 1996).

2. SEMIOTICS TO ANALYZE SEMANTICS

Semiotics is a field of studies that embraces many forms of research regarding systems of significations (Eco 1986). Eco states that semiotics is concerned 'with everything that can be taken as a sign'. Semiotics implicates not only the notions of systems of signs, but of anything that stands for something else (Chandler 2002). Two paramount theories regarding the definition of signs are those of Ferdinand de Saussure and Charles Sanders Peirce. Saussure, a Swiss linguistics, stresses that sounds and thoughts are inseparable. He became a founder of semiotics and the focus of his semiotic model is on linguists sign. Peirce was an American, prodigious, brilliant, and productive scholar, the founder of pragmatics (Hoopes 1991), and largely known for his contributions to semiotics. The notions of Peirce's proposition on semiotics are adopted in this research and articulated within the construction domain on the fundamentals of significations.

Peirce also founded his theory of semiotics on three fundamental ontological categories, firstness, secondness, and thirdness. This trichotomy is a metalevel principle that can be applied repeatedly to generate new categories (Sowa 1999). Firstness is the representamen: the form that the signs take, which can have the quality of material. Secondness is the interpretant: it is not the interpreter, it is the effect of the sign on the interpreter. Thirdness is an object: it is semantic beyond the sign to which it refers.

Peirce used his trichotomy to organize signs according to Material, Relational, and Formal aspects. The first category is a Material trichotomy that consists of Qualisign, Sinsign, Legisign; Qualisign is a sensory experience originated due to stimuli of some material on the actors' senses. It has not reference or any additional indication to identify a meaning on it, but it has a character of being qualia. In the broad sense of the term, 'qualia' refers to the phenomenal aspects of the actor's reaction. In its relational aspect, sinsign is named material indexicality and relates qualisign, or the perception due to stimuli, to an internal concept that resembles an entity or an event. Sinsign is the result of the recognition of the simple material quality or qualisign. The recognition assigns meaning or semantics to the qualisign.

Legisign's main feature is the essential character of obeying a social consensus about the semantics of a particular concept. The formal aspect of sign, Legisign, has a force of convention or a social understanding of the sort of recognized sinsigns. Legisign is under a mediation category, which indicates that the actor's reasoning does not add additional semantics to the interpreted sign. From the metalevel trichotomy, there are additional classifications of signs according to material, relational, and formal aspects.

2.1 A semiotic experience

A semiotic experience involves an actor's reasoning processes about the interpreted representations and the actor's role or intentionality in employing that representation. This experience motivates this research to inquire about the form of the correspondence of the perceived entity, event, or relation, with the concept in the actor's mind. In addition, the purpose of this experience is to provide direction to the method of how semantics aspects should be understood to give interpretations for concepts employed in the construction industry. This section provides an analysis of the forms of representation for the construction management domain case.

The best way to explain a semiotic analysis for representations is through examples derived from its corresponding semiotic theory. Thus, setting up a framework for interpreting the nature of the construction domain

concept representations is facilitated. Accordingly, the following analysis is based on Peirce’s theory of signs and his triadic notion: independence, relative, and mediating.

Signs, as Pierce defined is “is something which stands to somebody to something in his capacity” (Hoopes 1991). They are external to the agent, who is responsible for the thoughts and actions of the individual to which they are ascribed, and they do not have meaning unless interpreted by a subsequent thought. Signs, under the semiotic experience, are representations that contain meanings and purposes, which are prescribed by Peirce’s trichotomy independence, relative, and mediating.

The representations used in the construction domain practices are a collection of visual representations and text-based documents. The collection is a set of markers that describe a formal language and of markers that are used to represent natural language (Mutis 2007a), including other possible marker collections, such as a collection of hexadecimal numbers. Therefore for the proposed analysis based on Peirce’s semiotics, the language that is commonly used to describe symbols is replaced by the terms used in semiotics for signs. A semiotic analysis is an examination of the compromise between the meanings of a representation per se and the concept associated with the understanding of such representation (Danesi 2004). The analysis gives a perspective from the nature of the understanding of the concept from each one of Peirce’s categories.

Consider Figure 1. “Firstness is the conception of being or existing independent of anything else. Firstness is shown as an independent ontological category in Figure 1. The set of markers does not constitute a sign and does not have any source of semantics unless the construction participant relates them with Secondness. Secondness is the conception of being relative to, and reacting with something else. The construction participant reacts and perceives a representation. In Figure 1, this actor reacts to the text and the visual representation. The texts are syntactic representations and the visual representations are the icons in Figure 1. Thirdness is the concept of mediation, whereby a firstness and secondness are brought to a relation. The actor employs the perceived representations and mediates them to a concept to the thirdness category. The actor interprets the representations and mediates the perceptions to semantically find a relationship to a specific concept. The actor in Figure 1 mediates the perception of the construction concept “valve”.

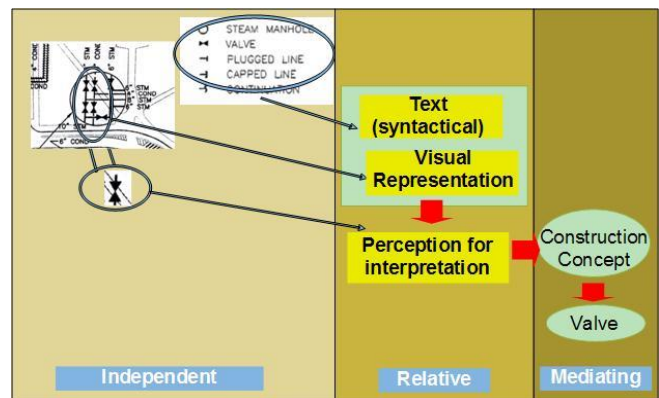


Figure 1: Signification Process

The following section presents Peirce’s framework according to Material, Relational, and Formal aspects of the signs organized within the trichotomies. The first and Material trichotomy consists of Qualisign, Sinsign, Legisign; the second trichotomy consists of Icon, Index, and Symbol, and the third includes the Rheme, Dicot Sign, and Argument.

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Qualisign. Qualisign is a sensory experience originated due to stimuli of some material on the actors’ senses. It has not reference or any additional indication to identify a meaning on it, but it has a character of being qualia. In the broad sense of the term, ‘qualia’ refers to the phenomenal aspects of the actor’s reaction. Figure 2 shows a representation, which in this case should be perceived by visual senses. Any actor can perceive it through visual stimuli. The source of this stimulus is a ‘contrast’. This first distinction that the actor possesses by contrasting a representation is a sensory experience. Qualisign is simply the sensory experience and, as an experience itself, it is independent of the source. It has the same quality as an appearance. Qualisign is founded on Peirce’s firstness category, which is independent of anything else. In the example, the visual representation contrasts are themselves independent from the source. They could have originated from printed drawings on paper, or from a computer screen. When the agent perceives the representation, here by visually contrasting dark and light, a set of relationships originating from what is perceived are internally created within the agents mind. These relationships are used to create distinctions in the actor’s mind.

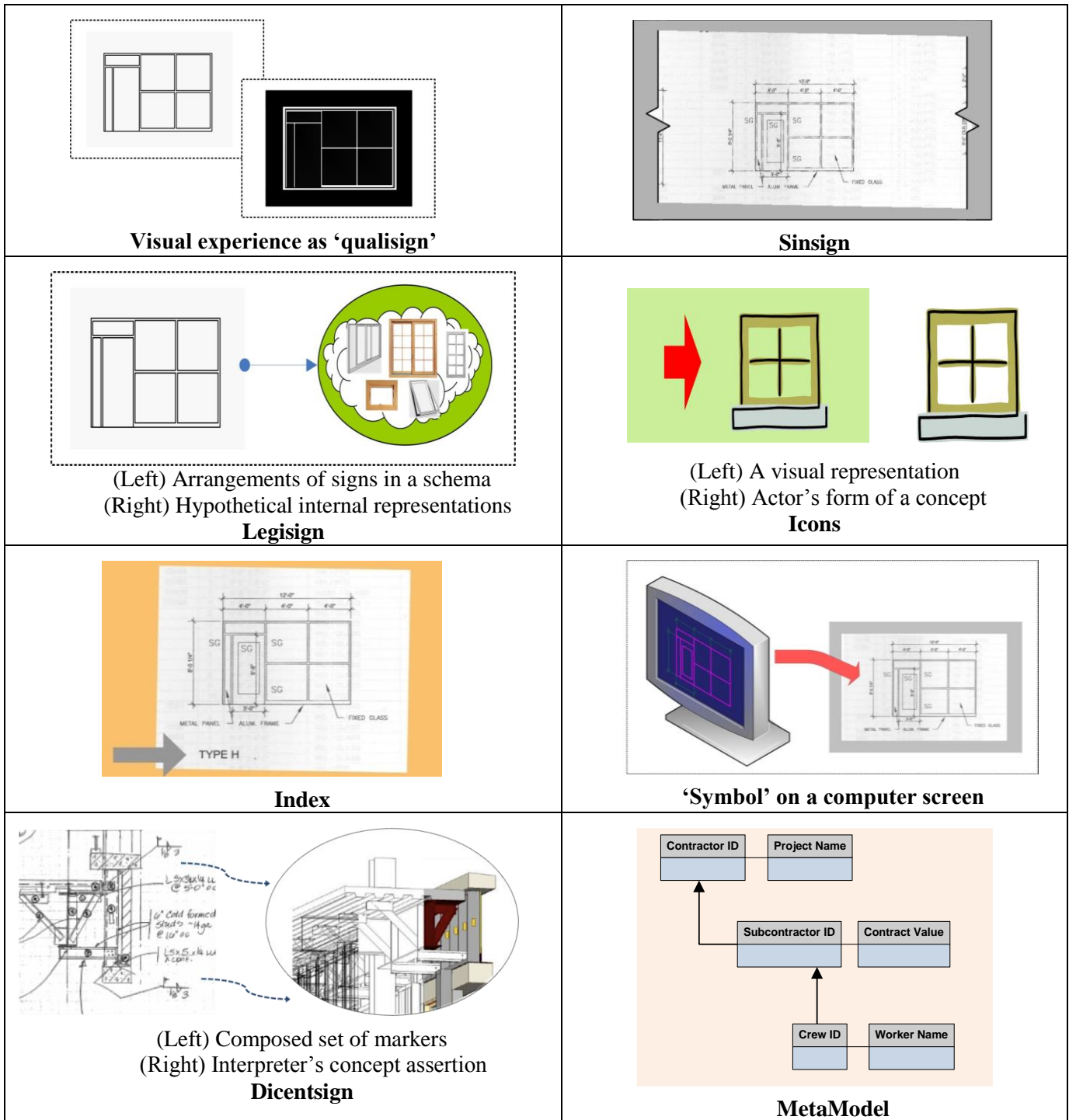


Figure 2: Examples of material, relational, and formal aspects of the signs.

Sinsign. This category is named material indexicality and relates qualisign, or the perception due to stimuli, to an internal concept that resembles an entity or an event. Sinsign is the result of the recognition of the simple material quality or qualisign. The recognition assigns meaning or semantics to the qualisign. The assignment of relations to the perceptual experience is the identification of semantics. According to this tradition, it takes place in secondness.

The fact that sinsign has been identified implies the recognition of a particular mental construct or concept within the actor's mind. In the semiotics experience, the source is recognized by perception and it is related to a specific source that has previously been understood by experience. Figure 2 shows a section of drawings that are chunks of traces of ink on paper and are recognized as a source that allows assigning meaning to the traces of ink on paper as drawings. In other words, this recognition identifies the concept drawings by visual perception. In the Figure 2 example, the recognition of this visual perception implies a match within the actor's mind of an a priori, learned, piece of drawings concept. However, the recognition of pieces of drawings does not imply the definition of the convention or a consensual semantics of the sinsign.

Legisign. Legisign's main feature is the essential character of obeying a social consensus about the semantics of a particular concept. Legisign has a force of convention or a social understanding of the sort of recognized sinsigns. Legisign is under a mediation category, which indicates that the actor's reasoning does not add additional semantics to the interpreted sign. Legisign identifies the convention or social understanding of such a particular concept. If the representations correspond to legisign, the actor's reasoning about the meaning of the perceptions identifies that the representations or signs have relations to the learned and socially agreed upon concept, and performs assertions about these relations. These relations are inferences from previously learned concepts within the actor's mind.

The lack of social consensus about a concept, an agreement, or an enforced legislation negates the possibility of considering a representation as legisign. The meaning of a concept is shared in commonality within a network. The understanding of the signs is based on a common set of constructs that constitute a concept. The interpretation of sinsigns can be a positive reaction towards an association of a previous, social consensus. If this reaction is performed, the interpreted sign are considered legisigns. In the example, the visual distinctions of a group of parallel and perpendicular lines grouped in a certain layout infer a form of a window in the agent's mind. In the example of Figure 2, the distinction grouped implies the identification of an arrangement in a layout of parallel and perpendicular lines. The 'arrangement' of lines corresponds to sinsign, which corresponds to the schema shown in Figure 2. The result of the association of the 'arrangement' into a concept that resembles the concept 'window' is a legisign. The concept 'window' was learned a priori and corresponds to a socially agreed upon concept that is supposed to have a definition that stands for: a physical device that isolates two environments by keeping a visual contact between them. The convention of the window definition should resemble multiple a priori mental constructs that meet the description of this definition. Figure 2 illustrates the hypothetical internal representations for a certain agent that stands for the concept that resembles the a priori learned concept of windows.

Icon. This category is part of the relational trichotomy, which is determined between a representation and an entity. A sign is a representation when it is recognized per se as a representation for the cognitive agent. To define an icon is to define a resemblance to a concept in the agent's mind. An icon is a representation that resembles a specific entity. The distinctions of the icon as an entity are possible as a result of the learning process within the actor's mind. The cognitive agent interprets it by establishing relations or finding semantics. The representation is not interpreted as qualia or as pure material, but the nature of the material has the quality to be recognized as a representation by the actor. The relations that the actor identifies are apprehensions based on similarity. The similarity is a property of the perceived phenomena and it is employed to find relations to the mental construct of the actor. Similarity does not designate the characteristics of a concept. It establishes general indications of what a representation of a concept refers to.

An icon through the effect of the similarity distinctions does not implicate true existence of that entity. An icon makes clear the resemblances to a concept that has been a priori elaborated. The primary distinction through similarity in the agent's body of knowledge does not assign further semantics to the icon. The similarity is a contrasting reasoning that formulates indication to a concept. Figure 2 shows an example of a representation that is visual. The form of the representation resembles a concept that the actor is already familiarized with and which is depicted in Figure 2. This a priori, primary, distinction is derived from similarity contrasts, and it is supposed to resemble a concept, in this case, the concept 'window'. Icon distinctions depend on the cognitive agent's experience. Thus, in the example the representation could resemble the habitat of insects or the design of a marine, emergency flag.

Index. The constituents of index are markers or icons whose semantics exclusively indicate a relation to a specific concept. An index loses its semantics if it does not react upon a concept, i.e. it 'declares' the existence of a

concept. The index's semantics function is to afford the existence of a concept. An interpretation of the concept can be guided by the index, although the index may not be necessary for its interpretation. The index serves to make connections to a concept in the cognitive agent's mind. The indication to the concept does not imply the distinction of the concept's properties or some additional semantics. Indexes provide nothing other than the indexical relation.

Although, Peirce suggested that indexes point to objects or facts, this study treats objects or facts as concepts that actors identify by stimuli. The concepts must be commonly recognized by social actors, i.e they are common, shared concepts. This particular, social, inclusion feature of index implies a purpose of sharing concepts among the community. This purpose, then, should make any index, by virtue of its semantics, be an artificial signal to point to a concept. The pointed or mapped concept, by virtue of the indexical relation, must be the same, independently from which actor performs the interpretation. A photograph is an index that can be read by any other actor, and the indexical relation always maps to the photographed entity. Under this social dimension, indexes map to a unique entity and they serve as an identification of that entity. However it is important to note that indexes are not 'identities', they are artificial representations that, under a social consensus, afford the indexical relation. The set of markers that compose a social security number can indicate identity or ownership of a boat. Index just points to a concept and social conventions convey the semantics of what is pointed at.

In Figure 2, the set of markers "Type H", at the bottom of the visual representation 'drawings', indicates a map to the concept 'aluminum windows'. This indication to the concept encompasses the set of showed constraints of size, of spatial arrangement of the components of the 'aluminum windows', and of the displayed values such as that of the concept's dimensions. The reasoning behind the "Type H" index consists of performing searches for matches to other representations that contain the set of markers "Type H" within a knowledge base. This knowledge base can be construction specifications, schedules or any documents that contains the representation, index "Type H". In the same way, the inference that acts on other sets of markers, such as the social security number index, searches for matches that are based on the similarity relation.

Symbol. Symbols are the result of a rule or association for a sign by virtue of the experience or of the learning ability of the cognitive agent. This rule governs the representation of signs or indexes. Symbols are the outcomes of the learning process that has shaped the concept for a particular meaning. The actor establishes the semantics of a concept by learning. When an actor recognizes a symbol, it is simply associated to a concept, i.e. the actor understands the semantics of that symbol with no additional inferences or aids from other sources for its comprehension.

Figure 2 illustrates a symbol on a computer screen. The symbol is an instance of some printed drawings. The actor associates the perceived signs with the concept drawings. At the same time, the actor identifies further semantics in each one of the distinctions performed and perceived from the provided signs on the computer screen. The role of the computer screen is to serve as a means of replicating the signs that represent the symbol of the concept 'drawings', or in other words instances of the concept 'drawings'. The computer screen mediates the representation of the concept drawings through the symbols on the screen. Clearly, the symbols are presented in visual representation form.

The agent can find additional associations for additional semantics during the resulting reasoning concerning the symbols on the computer screen in Figure 2. The additional associations are mediated through the signs shown on the screen. The screen mediates for additional associations or additional semantics in order to be distinguished by the actor. The lines on the top and the left side of the scheme on the computer screen are signs that add semantics to this visual scheme. The actor might read these signs as symbols for defining and delineating 'size' properties of the visual scheme. Therefore, the actor associates additional semantics to the mediated concept.

Rheme. This category represents a set of markers that afford a proposition or relation to some concept. Rheme are the makers that have been identified by the actor as signs that have a form of representation and that hold information of a concept. Rheme essentially represents the signs that belong to a formal language and that can be either natural or artificial. For example, the word 'bell' is composed of a set of markers that hold information about a concept: "A simple soundmaking device or a percussion instrument that has a form of openended hollow drum and resonates upon being struck." The markers 'b', 'e', 'l', 'l' as set hold this definition. The actors that perform the perception of the markers have learned the concept and they imply a consensus or a social concept description, which is part of the features of a formal language.

Rheme's components have the quality of qualisign and they can be identified as signs or markers; they can be recognized as representations. The resulting identification of the primary information of the markers is their recognition as a representation. Rheme affords some information that holds meaning to the cognitive agent. The information does not have any additional indication than the possible identification of a concept. The series of markers 'aluminum window' might afford the information for an actor about a material element that resembles the role, the form, and the properties of a window, which is made of aluminum material. This example takes an ontological account by naming properties and forms, with the purpose of explaining the possible concept characterization that an actor might possess. Then, the set of markers 'aluminum window' represents a qualitative possibility in a formal way in the example. Although Peirce (Peirce 1991) defines Rheme as terms that have the ability to conserve a blank in a set of a proposition, Rheme's definition can be extended to signs to be used in formal languages in general.

Dicent Sign. Dicent sign, also expressed as dicisign or dicent, represents a formal category of *indici*. Dicent sign is the assertion of a concept, which, in turn, is the result of identifying the semantics of the concept. The actor reasons on the perceived sign, shapes its semantic, and expresses an assertion. Dicent sign can be interpreted as true or false, but this interpretation is embodied. Then a truth or false character rests on the semantics that are refined through the distinctions made on the perceived entity. The actor's interpretation has the character of being true or false. Therefore, the sets of markers that compile the representation and constitute dicent sign have the capability of being true or false. The result is an assertion produced when the actor assigns semantics. Dicent sign affords grounds for interpretation and its purpose is to perform an assertion about what is perceived by the actor. Dicent sign can adopt indexation signs due to its nature. An example of dicent sign is as follows: the project manager makes the following assertion, "The subcontractor fixed the window." This phrase is an assertion built in natural language that is composed of a series of words that in turn are a set of markers that afford information and that assert the existence of an entity or event. In the example, the cognitive agent, who perceives the set of markers that form the phrase, might take for granted the truth or might reject the assertion. This means that the phrase still affords grounds for interpretation.

Argument. Argument is a sign that involves formality in the interpretation of a dicent sign and it falls under the formal mediation category. It is the reaction to the perception of a learned concept without further reasoning for finding additional semantics on the perceived sign. Argument has the form of law to the actor and does not give grounds for interpretations other than that intended. Although argument suggests an intended interpretation, the cognitive agent processes it as a definitive "belief." In other words, this argumentation is taken as "belief" and its reasoning about premises concerning the argument validity are not examined. For example, "The window must be made of aluminum, and not from any other metal." Therefore, the assertion is created to represent a constraint in the type of metal of a window. The interpreter or cognitive agent might vary the interpretation according to his or her belief concerning the meaning of aluminum metal.

The mediation level of argument represents a further result than the addition of semantics to the signs. The derived result of the sign perception and interpretation reflects intentionality. With argument, the intentionality reaches a level of formality, which does not require additional reasoning for assigning semantics for the actor. Clearly, the basic reasoning of argument consists of the identification that is learned and refined a priori. The basic argument for interpretation is regarded as previous knowledge. Problems of signification can often be found within interoperability situations. Suppose that one actor shares information with other actor in a construction project. One actor generates the information and the other receives it. They do not previously arrange meetings, nor do they work in collaboration for generating the information. The recipient obtains the information in tables as well as their corresponding metamodel. This metamodel is shown Figure 2.

In this example, the metamodel and the tables are forms of representation that are intended and structured to describe some instances of concepts such as the construction company budget. The recipient or interpreter's problem is to comprehend the semantics of the metamodel. From the semiotics standpoint, the metamodel satisfies the definition of *sinsign*, since it represents the recognition of the internal understanding of the diagram as a metamodel as well as the syntax of meaning of the words. However, the interpreter does not recognize the meaning of the relationships of these words within the metamodel. The metalevel does not have the character of a symbol for the interpreter. Thus, the metalevel does not embrace a mediation stratum where the social understanding of the arrangement of the shown entities has a social meaning. Therefore, in order to determine semantics on the met-

level, the interpreter will demand additional information from the source. The request for information is an activity that employs additional resources which raises the costs and reduces the efficiency of the interpretation of the representations.

3. ICONS

The intelligent geometric topologies for semantic interpretation of building components (iCon) are images that have the virtue of being a symbolic vocabulary. These images have an established use defined according to qualitative spatial relations, parenthood, and connectedness. The symbolic vocabulary is an artificial language built on three levels of representation: (1) physical similarity, as it is the first referent to one of the entities or to multiple, aggregate, or set of entities (e.g., one or multiple building components); (2) ontological, as in the relationships between entities, including their relationship with the physical space, and (3) semantics, as it defines the actual and possible associations and configurations, including the propositions that define the interpretation of the entities' interaction to situations.

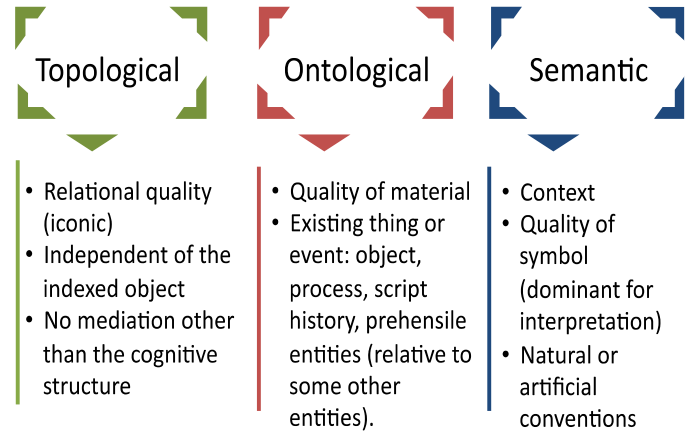


Figure 3: iCon's levels of representation.

iCons hold *independence*, which make the symbolic vocabulary independent from a specific situation as it is with syntax in natural language. Figure 3 shows a summary of the iCons' three levels of representation. These levels are aimed to categorize the imagery and to support the iCon vocabulary associations to an established use. The vocabulary has symbolic meanings. It uses conventions that have the force of operating rules. iCon's imagery and *symbolic* meaning are complementary to support the cognitive agent's reasoning. Although symbolic meaning is by nature arbitrary, the core of iCon imagery resembles shapes that hold qualitative spatial relations. For example, an image of iCon is linked to an established concept of neighborhood, which examines the primitive relations between regions of one object to its physical space or to other objects where their boundaries intersect. An example of the association of iCon image to the physical object is shown in Step 2 of Figure 3, which is aimed to illustrate the spatial relations of the connectedness of two virtual physical components. The shown topology, an image of the iCon vocabulary, has a resemblance to the spatial relation of connectedness.

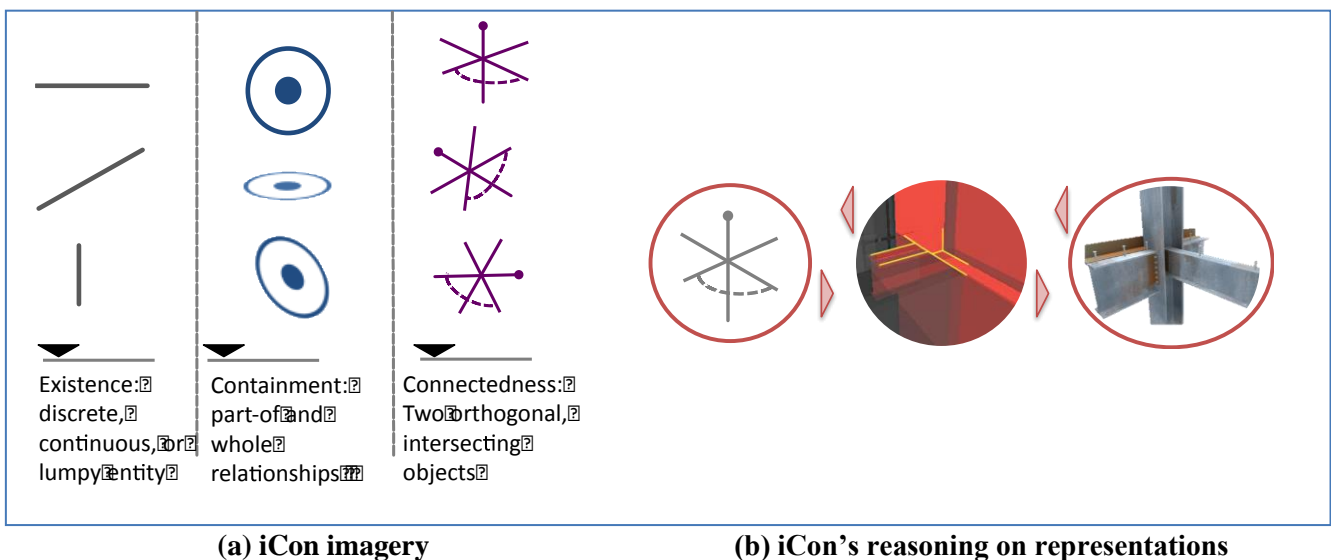


Figure 4:

The iCon symbolic vocabulary has extensions to basic operations that indicate actions (e.g. process, read) and to meanings to support intentionality (e.g., definition of interactions of two objects). These features are aimed at directing the attention to two cognitive agents that are the basic symbol manipulators, the interpreter and source (i.e., a discourse producer and discourse consumer in the natural language domain) on the state of affairs of iCon's associated physical objects. Figure 4 shows examples of iCon imagery. In Figure 4(a), each one of the images is part of the iCon vocabulary framed in the three layers of representation (as shown in Figure 4). The shown topologies have basic emerging semantics and geometric resemblance. For instance as shown in Figure 4(a), the image that resembles a line represents the *existence* of a continuous, discrete object. The ontological representation is the proposition of the existence of an independent, physical object. In propositional logic, this existence is represented through the existential quantifier (\exists), which reads as 'there exist an object y such that'. iCons' imagery can be placed in any position in a three dimensional Euclidean space, since the iCons purpose is to represent the vocabulary through any computer graphics applications that supports three dimensional modeling. Therefore, iCon imagery represented through computer applications affords 3D image generation and object simulation, including properties such as rotation, intersection, reflection, and refraction. Figure 4(a) shows three positions of the existence, containment, and connectedness iCon vocabulary in three dimensional Euclidian spaces. Therefore, iCon vocabulary has the ability of being identified in a three dimensional space mediated by any computer application.

4. EXAMPLE

Consider the case of a transaction exchange using construction documents between a designer and a trader. For instance, a Request for Information (RFI) made by the Trader A to the designer regarding an action on the roof level at location A1. By having an iCon imaginary on the message of such request, the designer will have the ability to easily associate semantics and reduce cognitive reasoning processes by using, in this case, indexation properties (see Figure 5, iCon directs the attention to two cognitive agents). Any index by virtue of its semantics is an artificial signal to point to a concept. The concept is the physical relationship of connectedness associated to roof and steel beam. The pointed or mapped concept, by virtue of the indexical relation, must be the same, independently from which actor performs the interpretation. Therefore, by mapping the concept from the RFI to each one of the artificial representation (construction documents) as shown in the Figure 6, the index enables to perform inferences with the purpose of finding matching to the identified entity. The connectedness iCon has a convention role. An index has the character of being dependent on the mapped object. It is an artificial representation that can exist by itself. Although this is an illustrative example, iCon imaginary can easily be implemented to be used in graphic engines to enable automatic inferences in order to assist the actors who interpret the proposed vocabulary (in the example, the connectedness iCon).

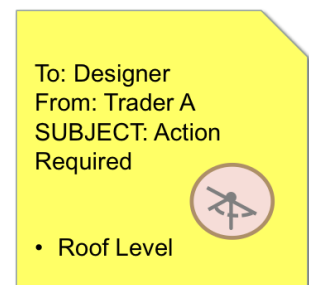
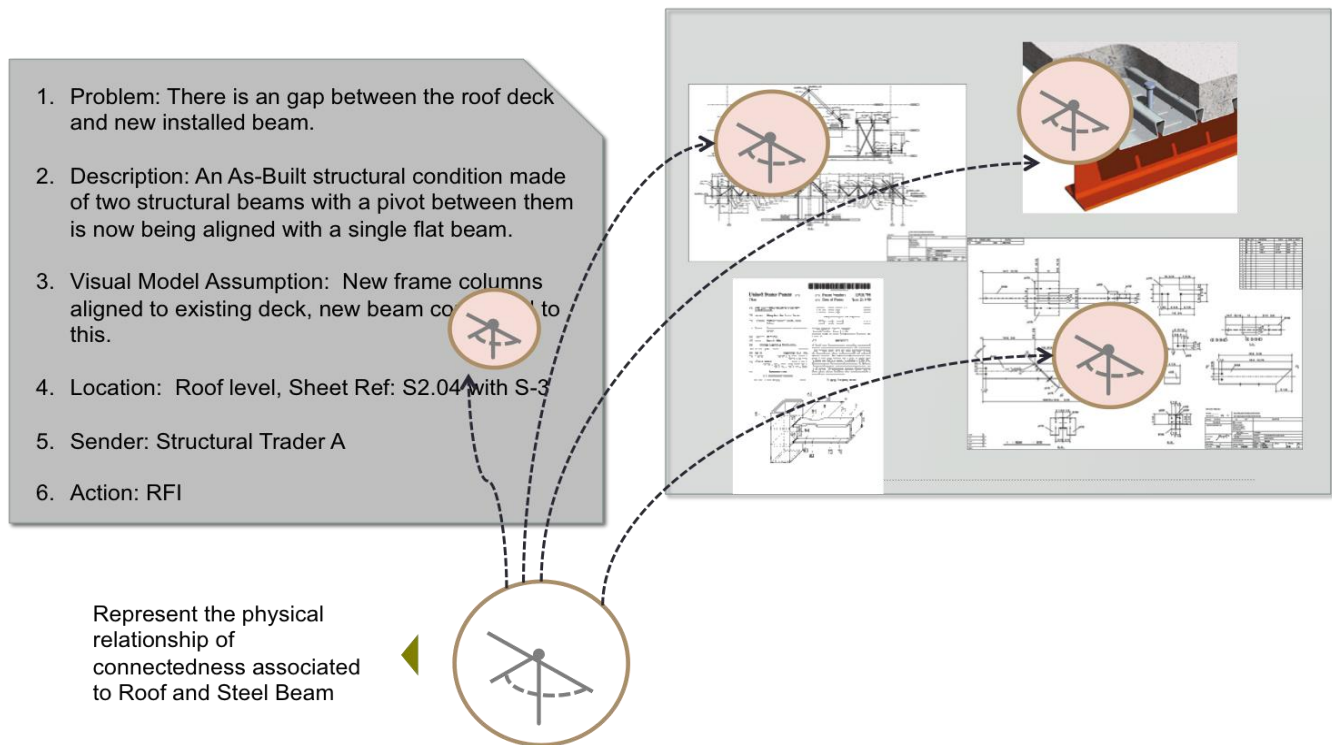


Figure 5:
Connectedness Icon.

5. CONCLUSIONS

This research proposes intelligent geometric topologies for semantic interpretation of building components (iCon) based on a semiotic framework to streamline the communication of designs, by enabling the agent to observe aspects, details, and geometries through the iCon vocabulary. The iCon vocabulary has the ability of being identified in a three dimensional space mediated by any computer application. With the use of iCon imagery, a reduction of the cognitive agent's effort to efficiently arrive at less ambiguous design interpretation is expected. In addition, iCon use is aimed to represent propositions of intentionality by indexing data. This feature will further bring an explanatory meaning to the intended physical referent of the building components, since static visual representations (e.g. components of BIM, and 3D images) are limited to the individual's point of view of the design. The successful implementation of iCon vocabulary has the potential to transform methods of communicating semantics within all range of practices in civil and construction engineering and management projects.



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