SEMANTIC STRUCTURES FOR CONSTRUCTION CONCEPT INTERPRETATIONS

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ABSTRACT

The interpretation of any construction concept during the construction process of a project is performed by reading and integrating or assembling drawings, construction specifications, and other construction documents. Drawings are visual representations of a construction product, while specifications and construction documents are text-based representations. The mapping between these visual representations and the text-based representations is a convoluted or intricate task because it requires complex synthesis and high levels of expertise. Accordingly, the constructor's interpretation of the construction concept relies entirely on the construction participant's experience instead of the full, integral interpretations of the available representations of the intended product. Interpretation problems may arise for new or innovative concepts as well as unknown concept components.

The purpose of this study is to analyze where the problem resides and propose a strategy that will use a semantic structure to aid the interpretation of representations. Visual representations are elaborated by extension, while text representations are mapped to multiple possible instances by intention. Therefore, the strategy used in this study takes into account the traditional reference problem and adopts a pragmatic approach. This approach fills the gap between the representations and the intended concept by using a semantic structure. This structure is composed of a conceptual base that identifies: the meaning of the concepts; the possible concept perceptions; the pattern of their topological structure; the functional structure; the metaphorical views; the meaning of the associated syntax by pragmatic analysis; and intention of the concept representation.

KEY WORDS

concept cluster, construction concepts, ontology, semantic interoperability

INTRODUCTION

Construction project participants are committed to building projects based on representations such as drawings and specifications that they have been furnished within the construction documents. This type of information will help them in understanding the scope of the

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specific activities of the project. Concept descriptions are embedded in specifications, regulations, and other project documentations. Concepts are abstract, universal notions, of an entity in a domain that serves to designate a category of entities, events, or relations. Concepts are represented in two forms as a physical construct or as an abstract expression (e.g. drawings are visual representations of construction concepts, while specifications and construction documents are text-based representations). Designers rely on project documentation to communicate the design intent, and contractors rely on it to *interpret* the design intent. The intent is the purpose of the representation. The purpose works in two ways: as the purpose of the author of the representation and as the purpose of the interpreter or reader of that interpretation. This research focuses on the interpreter or observer's purpose, also known as the cognitive agent's purpose.

In the construction domain, a purpose can be defined as a deliberate thought that a construction participant seeks through a goal. This research acknowledges that the relation of one agent has with the concept is the agent's cognitive thought about the concept. Our study assumes that the purpose of a representation of the concept is the actor's awareness experience. When two different agents have the same relationship with a concept, they are aware of the same concept purpose. For example, a designer is committed to build a representation to communicate a purpose and the contractor attempts to recognize the designer's purpose through an interpretation of the representation.

A framework that expresses the fundamentals of the interpretation during an interoperability activity will be elaborated, in this study. This framework is labeled *'concept cluster'*. This structure will populate a knowledge base that identifies: the meaning of the construction concepts; the possible concept perceptions; the pattern of their topological structure; the functional structure; the metaphorical views; the meaning of the associated syntax by pragmatic analysis; and the intention with the representation. The approach attempts to find the right *concept cluster* for the right representation intension (connotation). Therefore, the actor will have a sufficient construction concept salience to perform interpretations.

Our study presents some aspects of the concept cluster in on which the fundamentals of this approach are based followed by an example of the proposed structure.

INTENSION OF THE REPRESENTATIONS

The problem concerning the determination of the correct interpretations resides within the *intension* of the representations[4]. *Intension* means the *sufficiency* of the set of properties, details, conditions, and other features which give and apply meaning to a concept.

Actors interpret the intent of the construction concept, say construction concept "wood frame window," by reading concept intension. Full description of construction concept involves maximum, possible intension. This research states that according to the concept of intension, the larger the number of sets of properties, details, conditions, and other features are available to perform a concept semantic analysis, the smaller amount of possible instances or extensions are possible. Therefore, the actor is able to perform plausible interpretations.

[4] The reader must realize that intension with 's' is not the same concept as intention with 't'

Within any semantic interoperability activity conducted during a construction project, actors make plausible interpretations through assertions made when construction representations are examined. However, there are high risks of incongruent, or inconsistent, interpretations when the *sufficiency* of the information does not meet the actor's ability to perform interpretations (Hobbs 2002). For example, construction participants' interpretations, which are made by using only one source, such as specifications documents, are error prone. If the *sufficiency* of details and situational conditions is not satisfactory in performing correct assertions of the interpreted construction concept, the result is that the interpretation activity becomes inefficient. Construction specifications, which are in text-based format, are semantically poor and do not fully explain concept details. In addition, the description of concept conditions is ambiguous and does not represent the evolvement and progress of the construction concept.

The lack of *sufficiency* of information compels construction participants to make interpretations based on their own experience and to perform possible incongruous decisions in the advancement of the related construction process. The correct interpretation should lead construction project participants to make decisions in full compliance with the intent of the representation and should involve less potential conflicts.

In summary, the intensions of ordinary construction concept representations such as drawings or specifications do not fully describe a construction concept. Vagueness, randomness, and uncertainty exist when a construction participant interprets those concept representations. The interpretations are developed based on the observer's perception of the details and situational conditions of those concept representations. When the *intension* or the *sufficiency* of the set of properties, details, conditions, which give and apply meaning to a concept to elaborate an accurate interpretation, are not enough, the actor is forced to find other sources of information that complement the set of properties of that concept.

PURPOSE OF PLAUSIBLE INTERPRETATIONS

Construction documents, which in this research are defined as representations that describe construction concepts, help in the specification of the *extensions* of the representations within the actor's world. *Extension*s are mappings of the meanings of a concept to objects or instances within the real world. It is important to clarify that construction participants perform *assertions* through the interpretation of the representations. These *assertions* are interpretations of the purpose that the construction participant holds as well as the interpretation of author's purpose with that representation. For example, consider the interpretation of architectonic drawings of some dry walls on one floor building by a subcontractor. In this interpretation, the interpreter is the subcontractor, the author of the representation is the architect, and the intended concept is a drywall concept for the subcontractor and for the architect. The subcontractor must determine possible meanings of the drawings and the purpose that the architect had in creating the representation. With this representation, the subcontractor must find additional semantic relations, add context relations, and map other sources of information such as document specifications. The asserted *interpretations* or *plausible interpretation* are *propositions* made from the interpreted *drywall* concept and *propositions* of the semantics of the *drywall* concept *conditions*. The subcontractor selects an interpretation from a possible set of interpretations within his world. The set of interpretations is termed possible worlds. Finding *context relations* helps subcontractor discover the *intention or purpose* of the *drywall* representation in order to perform the aforementioned assertions.

INTERPRETATION AS A COGNITIVE PROCESS

Interpretation is a *cognitive process* that involves mappings of representations of several sources. Although a mapping of several sources is not essential when performing an interpretation, a mapping from more than two sources produces more certain assertions than those that are derived from only one source (Mutis et al. 2005). In construction projects, mappings are critical in performing accurate *assertions*.

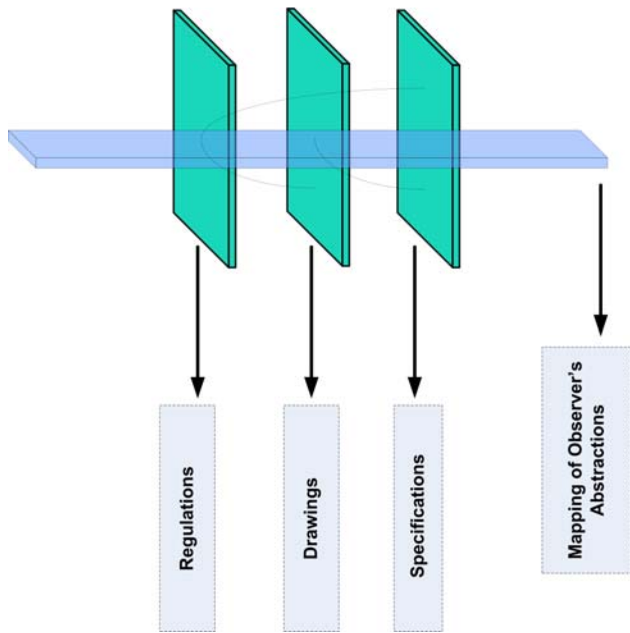

Figure 1. Mapping representations (layers) that describe the same concept

As was previously mentioned, when the *intension* or the *sufficiency* of the set of properties, details, and conditions, that give and apply meaning to a concept are not enough to elaborate a correct interpretation, the construction participant is forced to find other sources of information that complement the set of properties of that concept. In other words, construction participants map various representations that aid them in the understanding of representations of construction concepts. Mappings are matches of abstractions of a construction concept that has several representations, or that is described by more than one representation. Figure 1 provides a sketch of mapping representations described within three layers: regulations, drawings, and document specifications. In Figure 2, the mappings are performed by an observer of any construction concept; for example, a construction concept, such as 'a wooden ladder', that was created by a designer (e.g. architect) and that is interpreted by an observer (e.g. contractor) by mapping together the ‘wooden ladder blue prints’, the specifications for ‘wooden ladders’ (e.g. fire protection layers), and the local regulations about ladders (e.g. safety details).

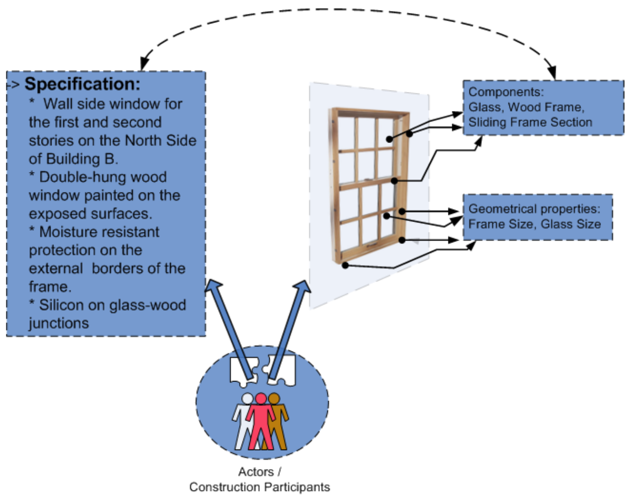

Figure 2. Relations between visual and text-based symbol representations

The mappings are not simple connections of concepts; they are links that find semantic relations among concept representations. The relations are not only found among the details, but also with situational conditions which help interpret the representations by examining states of affairs and context relations. For example, Figure 2 shows mappings of the visual representation’s components with text representation components by construction participants. They map the visual representation (Wood Frame, Double Hung Frame’) to the text-symbol (‘Double-hung Wood Window’) from the specification documents. In addition to the visual representation symbol details (e.g. geometrical properties in the visual symbol such as frame size, or glass size) and descriptive details of the text representation (e.g. silicon on glass-wood junctions), actors identify additional situational relations such as set on (e.g. set on a wall), or split by (e.g. split by internal and external environments). These mappings are motivated by the cognitive agent purpose. In other words, the actors find correspondences according to their intentions that they have with the representations. As the reader can infer from the above explanation, the mappings or semantic relation include a reasoning process.

REPRESENTATIONS AND INTERPRETATIONS

Representations attempt to describe an extension of a concept in the real world. The representations themselves are simple *metaphors* that give meaning to some concept (Gärdenfors 2000). Concept representations are not merely elaborations of signs in the mind, but are extended to something physical, such as the context space, in order to be realized or instantiated (Emmeche 2004). This means that representations of concepts cannot fully describe the meaning of the concepts if relations to the other concepts are not taking into account (Searle 1995). These relations are termed *contextual relations*.

Contextual relations attempt to identify a possible agent's relations, which might influence the current concept interpretation, and to link such relation to other concepts. This line of characterization of the interpretation has roots in the semiotic tradition (Luger 2002). The *contextual relations* rest on the cognitive agent's purpose in interpreting a concept. This research takes *contextual relations* in consideration of a valid construction participant's interpretation.

In order to represent concepts formally, not only a *conceptualization* but also a structure that gives form to the concept are required. As was previously mentioned, *conceptualization* is a set of *informal rules that constrain* a piece of a physical construct concept or an abstraction (Guarino 1995; Guarino and Welty 2001; Zúñiga 2001). The description of concepts can be executed by *conceptualization*s using specific syntax from any language. This research suggests that a framework for *structuring* concepts in a specific domain (e.g. construction domain) must be useful to construct them. At the same time, the *conceptual framework* should contain aspects of the representations concerning how they could be represented computationally. The goal of including computational aspects is to structure the information of the concept for future implementations. Although the computational aspect lies outside of the scope of the current research work, it is anticipated that this framework will contribute in the removal of some traditional knowledge representation limits about contextual knowledge, combinatorial explosion, and cognitive interaction of the observer and the world.

The aim is through the use of the framework to approximately connect the observer's world or cognitive agent's world to the representation of the construction concept. This research claims that an *a priori* conceptual analysis, which takes into account the cognitive agent purposes, will facilitate a future agent's interpretations. The framework guides this analysis and helps to define concepts and to launch a scheme to create computational representations of these concepts.

CONCEPT CLUSTERS

The last step of the *conceptual framework* is the analysis of the information in order to obtain an interpretation. This approach derives an abstract structure, called *concept clusters*, from the level of representations and from the explained framework scheme. The research names this structure *Concept Clusters*. The structure gives a discriminate description of the components and relations of a concept. *Concept cluster* provides links to clusters with the purpose of helping cognitive agents interpret a concept according to their intentions. Figure 3 illustrates the scheme of the proposed *concept cluster*. These *concept clusters* define additional *semantic specifications* of a concept. The *semantic specifications* are defined in *clusters*. The cluster groups are specified by pragmatics, contextual relations, intention, part whole-relationship, topology, cognitive agent role, and possible metaphors that represent that concept.

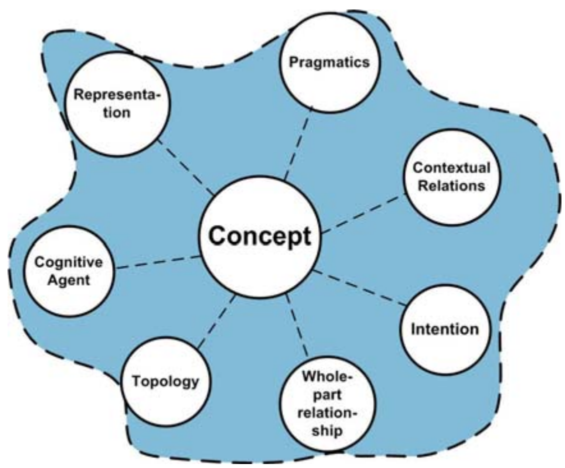

Figure 3. *Concept Cluster* structure

The analysis of the information used to derive an interpretation through the *concept clusters* structure is subsequent to the analysis performed within the schematic framework. It explicitly defines additional semantics according to '*conceptual links*' of the *concept cluster*. The strategy proposes a '*form*', which corresponds to *concept clusters*, that identifies additional semantic specifications. The 'form' is an assumption taken from the epistemological level analysis. The concept by itself is related to the clusters through '*conceptual links*'. These links are formal inferences made about a relationship between one concept and other defined concepts (Woods 1975). In this case, the links connect the formal concept to an additional semantic specification, which gives additional semantics to the concept. The links infer intended meanings of such a concept within the concept cluster structure. The structure holds the links facilitating the interpretation under the cognitive agent's view. As was mentioned previously, the view makes reference to the social role that the cognitive agent has in the organization.

As an illustration of the course of action of the analysis within the conceptual framework, assume that a construction participant, say, a contractor, needs to perform an interpretation of a "Rolling door" concept. Suppose that the construction participant only finds the "Rolling door" concept in a syntactic form or in text symbol representation in a construction document. In this case, "Rolling door" representation stands for a natural language form of a concept. Under the contractor's knowledge level, the cognitive agent's perception must be on the border of *sufficiency* to derive the analysis. For this example, suppose the construction participant's social role is "contractor". With the information of this analysis, the cognitive agent is able to query the concept clusters

So far the information obtained in the above scheme concerning the representation "Roller Door" and the identification of the agent's role as a contractor derives from the "Rolling door" representation that stands for a natural language form, the reference to physical object, the identification as an abstract scheme in natural language, the *situational conditions* (e.g. *location*, *position*, *site*, *place*), and the intention towards the representation concerning *why* the concept "Rolling door" is relevant for a "contractor" (e.g. installation of the metal curtain doors in a specific construction project). Concept clusters link other semantic specifications previously related in a structure that link and give semantics to the associated clusters. The structure shows additional semantic specifications that should be associated with the information extracted from the scheme. Figure 4 illustrates the structure and the links to each of the clusters. It is easy to observe that Concept-cluster links constrain the formal meaning through ontological commitments.

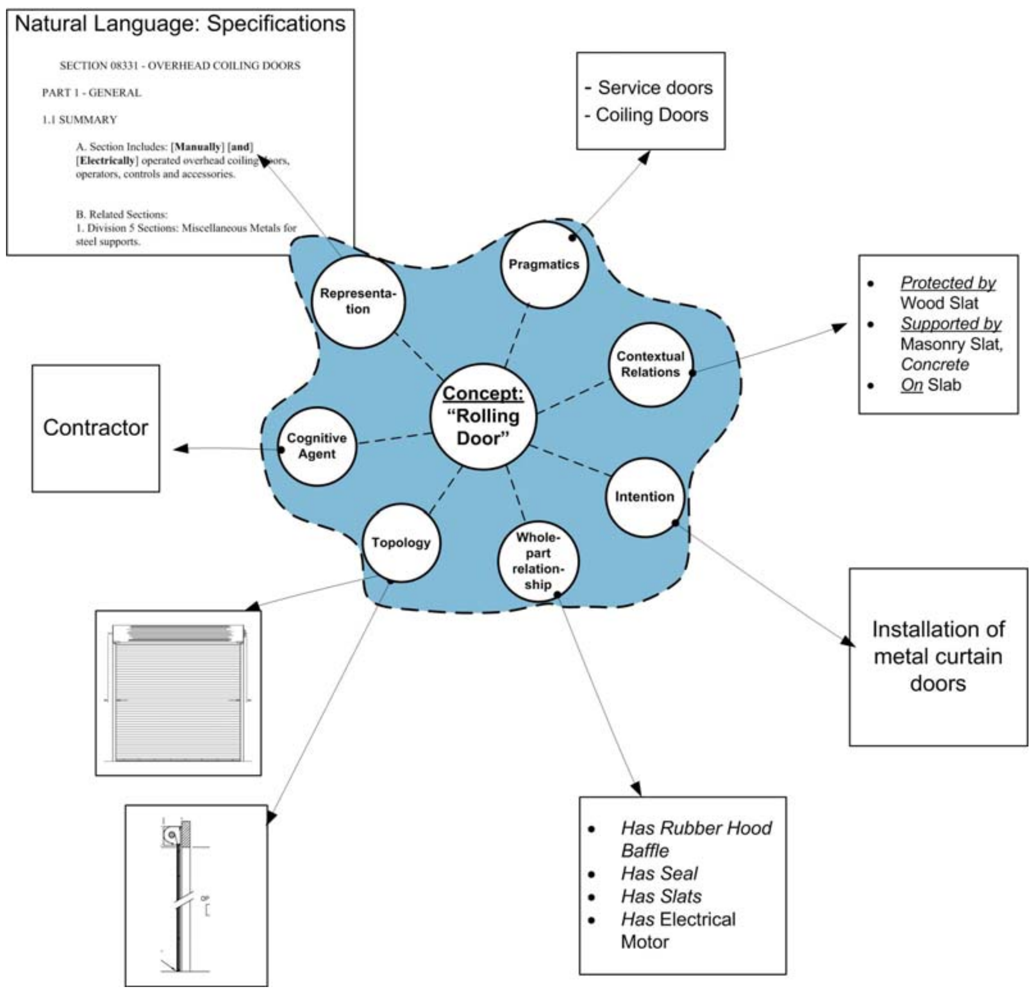

Figure 4. A concept cluster structure of "Rolling door concept

Figure 4 illustrates the '*form*' of the proposed structure and conceptual links to the clusters of the concept "Rolling door". In the example, the concept "Rolling door" is linked to the representation, pragmatics, contextual relation, intention, part-whole relationships, topology, and cognitive agent cluster. The result is that the syntactic form "Rolling door" that stands for the concept-rolling door is semantically associated to the following clusters:

- Representation. This cluster holds other type of representation such as the section of the specifications in the construction documents that describe “Rolling door”. As is shown in Figure 4, the representation in the cluster is constructed in natural language.
- Pragmatics. Pragmatics encloses the semantics upon pragmatic levels of a concept (Brachman 1979). The example shows two syntactic forms service doors and coiling doors that are other type of forms, which are equivalent to the form “Rolling door”, and which stand for the same ontological concept.
- Contextual relation. This cluster holds possible and strictly locative relations with other objects. These relations indicate the state of affairs of the concept. Their property is that they do not change with the states of affairs of the concept. The Figure shows the relations ‘protected by’, ‘supported by’, and ‘on’ for this type of object.
- Intention. The intention cluster contains purposes that the cognitive agents have with the concept and reasons of the interaction of the concepts to others. The purposes make explicit ‘why’ the concept is relevant to the cognitive agent. In the example, the “Rolling door” concept is relevant to the contractor concerning the installation of the metal curtain doors in a specific construction project.
- Part-whole relationships. This cluster supports relations that the analyzed concept bears as composite or as components of other objects. For simplification purposes, it contains only the significant composites, which are independent of the concept, as well as components, which are dependent on the concept. In the example, the primitive relation ‘*has’* to the components rubber hood baffle, seals, and slats and electrical motor composite is shown.
- Topology. Topology contains image or visual schema representations, which are metaphors that transfer information from the author domain to the cognitive agent domain. From these representations, the cognitive agent can induce the relation to the analyzed concept. Figure 4 shows two visual representations, which illustrate an image of the concept “Rolling door”.
- Cognitive agent. This cluster stores the available conceptualization of the agent’s social role in the organization. The assumption is that different roles in the organization make the agents identify a concept differently. In the example, the construction participant’s social role is “contractor”.

With the information obtained from the previous analysis, the cognitive agent is able to help in the interpretation of the “Roller door” according to the links provided by the *concept cluster structure*.

CONCLUSIONS

The current approach bases its analysis on the nature of the concepts within the real world, and not on the nature of the '*form*' of representation of a concept. *Concept clusters* link additional semantics of the concept that were analyzed in the *framework scheme*. The objective of this strategy is to capture the cognitive agent's intentions behind an analyzed concept, which is subjected to the agent's interpretation. The purpose of the each *concept cluster structure* is to group semantic specifications, which correspond by definition to the *intension* of the concept. The c*oncept cluster* accumulates the analyzed links in its *structure*. It groups a collection of semantic definitions viewed from the levels of representation, predominantly from an ontological level.

The proposed *framework* will aid the cognitive agent in analyzing the concept through the use of the *concept cluster* structure, and will assist the interpretation through the application. The *structure* links the analyzed concept to other semantic specifications.

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