THE INTEROPERABILITY ACT FOR EMCOMPASING SEMANTICS IN CONSTRUCTION DOCUMENTS

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ABSTRACT

Actors generate, share, and ultimately communicate information with other construction project actors. The content of this information is described within construction documents such as drawings, schedules, and specifications. Poor understanding of the content of the documents has been a factor in the escalation of construction project complexity. The result is a lack of efficiency in the communication that has been documented as failures to interoperate among actors during any construction process. As a consequence, actors need to employ additional resources for aiding the understanding of the shared information therefore significantly raising costs and reducing project productivity. Current research efforts are aimed at aiding interoperability by sharing common vocabulary and models among project actors. These efforts have been addressed through the development of common, shared models and construction industry standards. The objective is that multiple construction participants ultimately recognize the shared models and set a universal language. The implementation and use of the models and the common vocabulary provides the possibility of reusing the information within the construction documents by project actors. However, the industry has failed to adopt the commonly shared models and the universal language to effectively share information. The assumption in the construction industry is that the creation of an a priori consensus over the content of what is described within the information is a condition for interoperability. This paper questions this assumption by diverging into another paradigm, the semantics of the represented information. As an alternative, our research focuses on the semantic paradigm. We move away from the attempts to find consensus through common vocabulary and shared models to new methods that benefit from precise meanings. Our assumption is that strategies for exchanging, sharing, and integrating information will not reduce the lack of full automatic interoperability without working first on strategies for understanding the information from other sources.
One of the steps proposed here towards this paradigm is the interpretation of the represented information by other construction actors. Our research explores the relationship between the represented information and the interpreter. For this purpose, a parallel of the interpretation of shared information has been made through the Speech Act Theory (Searle 1969). The objective is to understand what background information is pertinent to the conversation and what assumptions and inferences are needed to capture the intended meaning within the expressed utterance in order to parallel the speech act with the shared represented information between two construction participants. This research proposes the interoperability act concept for construction documents. The significant implications of this effort are the characterization of the interoperability act with the purpose of developing new forms of representing semantics within the construction documents, which provide a method to successfully share and communicate information.

KEY WORDS

Interoperability act, construction concepts, interoperability actions, forms of representation.

1. INTRODUCTION

The common practice concerning the sharing, exchanging, and integrating of information for construction projects is that actors or construction participants generate their information independently rather than in a collaborative environment. The fragmentation conditions of the construction industry is one the reasons for the unsuccessful adoption of collaborative efforts. The resulting non-collaborative practices are also forced by the complexity of the project as multiple actors and multiple roles take part in a construction project. This complexity is reflected and increased when multiple actors that belong to external organizations actively participate in the same project. As these actors do not collaborate on finding strategies to share, exchange, and integrate the information, the format and content that the actors get from others is prone to misinterpretations, rework, and inconsistencies. The poor understanding of the content and format of the documents is an additional factor that significantly increases the construction project complexity. The possible agreements the actors reach on sharing, exchanging, and integrating their information are expensive and difficult to achieve. When two actors attempt to share and to integrate information generated from two different software companies, they need to set up business agreements regarding the functionality of their platforms and the methods of integration. Therefore, a priori agreements or coordination on the automation of the interoperability activities are not typically engaged in. As alternative strategies, the construction industry and government institutions approach the lack of effectiveness in collaboration with solutions that range from standards to common models initiatives. The ultimate objective is to facilitate the exchanging and sharing of information during the construction life cycle by moving all the actors to work in a single, public platform.

1.1 STRATEGIES OF CONSENSUS

The generation of common models, standards, and vocabulary, for example, is based on reaching consensus from experts and members of the community. Its final purpose is to achieve automation within interoperability activities. The resulting consensus sets up rules within a model where the actors are able to generate their information and to plan their interoperability activities (Eastman et al. 2008). The Industry Foundation Classes (IFC) is an extensible reference model that provides broad definitions of objects from where more specific models can be developed to support exchanges within workflow activities (IAI 2008).

The actors, for example, generate their information based on a set of rich classes. The objective is that multiple construction participants ultimately recognize the shared models and set a universal language. The implementation and the use of models and common vocabulary provide the possibility of reusing information by project actors. However, the modelers' view is limited to their social and physical contexts. Therefore, the consensus on setting a common model or vocabulary limits the final user's view or actor's view. The generation of information under the actor's view is limited by the modeler's view.
The set of entities that represent the model has to be further adjusted and extended by the final user to reflect their detailed needs of construction firm for a particular project. The modeler or expert sets up a universal language and common models by consensus. However the social and physical contexts of the individual actors are not embraced through consensus. The consensus strategy opposes the uniqueness of construction projects, as a feature of their nature. This fact is manifested as a fragmentation of the construction industry's workflow (Taylor and Levitt 2004) and the agents' systems (Anumba et al. 2005; Bakis et al. 2007) For example, as multiple actors and project teams participate within multiple workflows, these reference models have to contain thousands of definitions of workflows in order to define the exchanges of information for particular contexts.

An additional limitation of this strategy is that the granularity level of any construction concept is too complex in their levels of detail. The granularity is not possible to be defined a priori by the expert's or modeler's view. This limitation belongs to the realms of the modeling paradigm. It restricts the actor's ability to fully integrate information and, therefore, fully interoperate. A complete automatic interoperation without an actor's intervention cannot be executed. Actors are able to use models and common vocabulary as a reference, but they need to represent their view of the concept to be shared, exchanged, and integrate to others actors. Even if the information is generated from common models, standards, or common vocabulary, an interpretation of the represented information is still required.

1.2 RETHINKING AUTOMATION FOR INTEROPERABILITY

It is commonly overlooked that full automation of an interoperation is not possible and that a subsequent interpretation of the information is needed. A strategy for understanding the information from other sources is a requisite for an interoperation. The act of understanding involves interpretations. This research recognizes that the act of interpretation to generate and to represent concepts under the actor's realm is required for interoperability activities in construction projects. The interpretation takes place within two cases: 1) when the information that is going to be shared, exchanged, or integrated is generated, and 2) when the information is received and manipulated by other actors, different from the ones who generated the information. The fundamental assumption is that the act “interoperate with” has a purpose of communication and of induction of actions. An interpreter’s or actor’s reaction produced by the interpretation of the shared or exchanged form of representation is expected.

This research explores the relationship between the actor who generates the represented information and the one who interprets the information. An examination of the semantics of the forms of representation of the information that is communicated is performed together with the required elements that intervene for a successful communication. The objective is to explore the understanding of the semantics that is required to effectively represent the information and to define the basic steps for interoperability.

2. REPRESENTING, COMPUTING, INTERPRETING

The fundamental actions of interoperability are the actions related to the representation of information that is to be shared, exchanged, or integrated, the computation of the representation, and the interpretation of the obtained information by the recipients. As was explained in the introduction, the action that is probably most investigated in the past two decades is that of computing the representation. The transition from traditional paper-based to computer-aided-design representations is a representative case. The efforts have been focused on methods to represent and to compute representations in order to facilitate the interoperation. Researchers attempt to generate strategies to automatically interoperate the information with other actors (Barresi et al. 2008; C. Lima et al. 2005; Ducq et al. 2004; El-Diraby et al. 2005; O'Brien et al. 2002). However, the integration of the modellers’ views and the levels of specification of the representations is a paradigm (Amor and Faraj 2001; Mutis and Issa 2007) in AEC domain. This is a problem that is manifested in the semantic association of the representations (Motta 2000; Partridge 2002). As this research focuses on the action of interpreting, a brief examination of the currently used forms to represent information are useful to introduce the interpretative actions.

2.1 REPRESENTATIONS CONTAINED WITHIN CONSTRUCTION DOCUMENTS

The agents of a community generate descriptions of hypothetical objects and states of affairs of their domain through forms of representations with the purpose of communicating them. These descriptions are abstract and are grounded in the possibility of their existence, although they can be imaginary. An architect, as an agent of the construction-project network, can generate the description of a clay tile roof through a set of symbols, which can be systematically expressed in natural language. The syntactic set of symbols can be interpreted as an utterance in natural language and those utterances are indeed systematically interpretable as to what they mean (Harnad 1994). This description is a characterization of the clay-tile roof objects. The characterization can be expressed through the advantages of being energy efficient, fireproof, and long-lasting compared to asphalt or fiberglass shingles. The clay-tile roof description can also include its state of affairs within the space-time region, such as the suitability of its installation in hot and dry climates.

The objective of an architect or designer is to generate a representation of the set of abstractions. A representation is the vehicle where the actor’s abstractions are described. The representations correspond to the descriptions of the architect’s or designer’s concept and are subsequently communicated to other actors in the domain. The descriptions are a characterization of the actor’s concepts. In the preceding example, the architect represents the concept “clay-tile roof” concept through a set of syntactic symbols, “clay-tile roof”. The syntactic symbols are expressed in natural language. This syntactic-symbol representation is a text-based representation of a concept. The architect’s intention through the description of the concept “clay-tile roof” is to make a reference to a similar, existing physical object in the construction domain. The actor who makes the reference is the interpreter of the “clay-tile roof” symbols. In this particular case, the interpreter makes reference to an existing object in the domain, “clay-tile roof”. The architect, however, expresses a concept through a representation to indicate a non-existing concept. Those non-existing objects are the ones other actors will interpret and build in a construction project. A drywall with x and y sizes and specific shape cuts is an example of these types of non-existing concepts.

An architect, designer, or engineer represents information through representations of any forms, including visual, syntactic, and symbolic. These representations, then, are the vehicle of the actors’ abstraction of specific concepts. In the construction domain, concepts are represented through symbols, models, or visual representations and they are intended to be related to the physical domain, i.e. to be physically realized. The construction participant reifies and finds relationships between the interpreted concept and the physical domain. For example, a drawing of a "glass door" is a metaphor that represents a "'67lass door" concept. The metaphor or visual representation relates it to an existing object of the physical world, even though it does not exist.

2.1.2 REPRESENTATIONS AND THE PHYSICAL WORLD

The agents in the physical world perform an interpretation and transform physical objects through actions. The actors take materials and objects and perform some action in the physical world according to their interpretation of the representation. Therefore, the actors perform actions that are prescribed within the representations (Mutis 2007). These representations are contained in the construction documents expressed in any format, such as digital or paper-based.

For example, a construction schedule is a document and a representation that contains axiomatic rules, and it is employed for planning activities for a construction project. These activities are actions that are going to be taken in the space-time domain. The space domain corresponds to the physical domain of the construction project and the time domain to the planned order in which the actions (tasks) are executed by the project participants. The construction schedule is a representation that is interpreted by the actors, and it can also be directly manipulated by other agents, such as computers.

The actors' interpretations are semantic operations and the manipulations of the actors' representations are "computations" of the symbolic composition of the representations. The operations of some activities performed on the axiomatic hierarchy of the construction schedule are "computational" operations. These operations are based on a systematic symbol manipulation following a set of rules. The "computational" operations are not part of the semantic operations although they are interpretable, but they are manipulations of a systematic set of symbols. The semantic operations are based on the actors' interpretations. The actors link together the components of the representation in order to perform actions in the construction domain. These links, which can be either connect the representations to the domain or to other components of other forms of representations, are semantics. The agents' interpretations of and links with objects in the domain, actions, or relations to other representations are semantic operations.

Consider a taxonomical form of representing construction concepts, which can be employed for certain actives, such as estimating or planning. The assumption is that the actors translate their knowledge that corresponds to certain construction concepts into representations. The representation is tantamount to "languages of actors' thoughts". In this example, these thoughts are formally represented as a formal form. The resulting concepts represented by this form of representation must bear some relationship to properties, objects, or situations in the external world by virtue of that domain's nature, in this case, construction industry concepts. This formal representation contains relationships to other objects that are semantics of the intended concept. An initial exploration of the representation as a "language of actor's thoughts" was explored by Mutis (2007), through the introduction of conceptual role semantics (Greenberg and Harman 2006; Rapaport 2002) in construction concepts. This research further explores the idea of representation as "language of actor's thought" from the perspective of the philosophy of language.

2.2 INTERPRETING REPRESENTATIONS

The interpretation action in the simplest case takes place within two circumstances, as was explained: the interpretation that the actor performs to originate the representation, and the interpretation that the actor performs when he or she receives such representation. This research inquires after the relationship between the actor and any form of representation to investigate the grounds of misinterpreting representations.

In the interpretation step within the context of a construction project, additional aspects can be taken into consideration for a full commitment to the actions that follow the interpretation.

Consider Figure 1 for an illustration of this step. When a need emerges for information from other project participants during a construction activity, there is a directive act for requesting the information from these sources. As shown in Figure 1, the actors request information through previously defined and identified channels of information flow. The channel defines the method for requesting and providing information, which can be specified contractually or in agreements between contractors and subcontractors. The form of representation of the requested information can also be defined beforehand between the interpreter and the source.

Alternatively, the interpreter relies on the forms, syntax, and vocabulary of the sources for representing concepts as a viable, readable form for performing the interpretation. Once the actor or interpreter has received the information from the sources, an identification activity of the concepts that has been represented is performed. The identification consists of an analysis of the observed representation in order to perform reasoning for identifying meanings. The analysis is defined by the interpreter's intentional nature that motivates the requisition of information. In other words, the interpreter focuses on the representation sections that motivated the request for information and that are useful for his or her activity. The interpreter can also further articulate the sections or parts of the representation to complete the interpretation. The reasoning for identifying meanings consists of finding semantic associations from the observed representation with the interpreter's body of knowledge.

As shown Figure 1, if the semantic associations cannot be found by the interpreter for performing an interpretation, the sufficiency of "details" that describe the representation of the concepts is not satisfactory for the observer. The interpreter or observer searches for additional sources of information in order to find associations for identifying the concepts in the representation. The additional information can be provided by the interpreters' databases, knowledge bases, or even by experts. If the supplied information for finding semantics associations does not satisfy the interpreter for identifying the concept in the representations, the interpreter has to request additional information from the sources in order to have a better level of sufficiency for performing the interpretation. This flow of information is shown Figure 1.

When the semantics' associations satisfy the required conditions for the interpretation, the interpreter commits an action as a result of the interpretation. The conditions are satisfied when the intentionality with the observed representations is accomplished or, in other words, when an action can be committed by satisfying the purpose of interpreting the representation. This action is generally recorded in the actors' systems, or it is a part of a more complex, subsequent reasoning process for the interpreter, which can be manipulated and calculated.

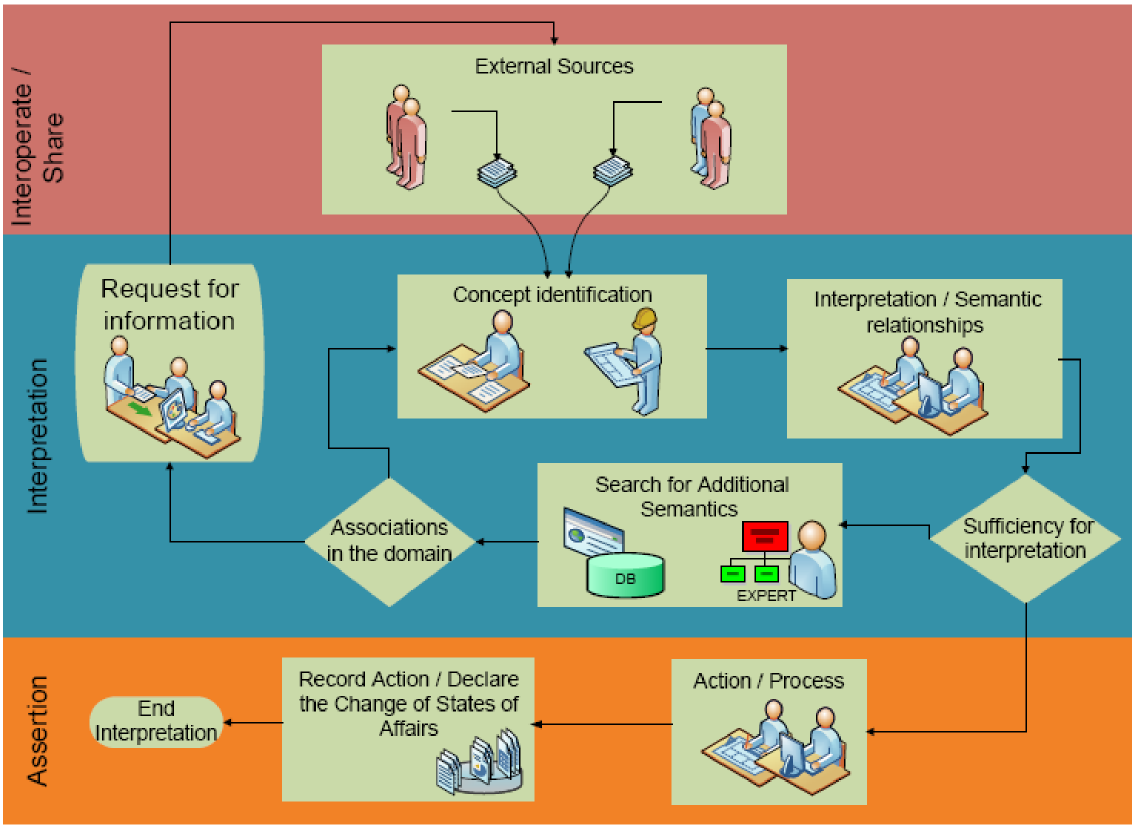

Figure 1. Interpretation process

As displayed in the work flow example in Figure 1, the representation is deficient for interpretation. The actor performs additional actions which increase the complexity of the activity and decreases the efficiency of the actor's activity. This research makes an inquiry within other realms that have advanced on formal investigations concerning the problem of misunderstanding semantics of representations. Speech Act Theory has played a central and exploratory role to inquiry of methodologies to accurately interpret representations in interoperability.

3. INTEROPERABILITY ACT

As this research exposes the need of the relationships between (1) the actors that originate the representation and the representation, and (2) the actor that interpreters the representation and the representation, a method for further investigation of these relationships is required. This research borrows a theory from the philosophy of language to examine these relationships and to illustrate the elements involved within interpretations of an interoperability activity. Philosophy of language provides descriptions of certain general features of natural language, which are concerned with semantics and ontological characterization, among others. Natural language is composed of a set of syntactic symbols that are forms of representations. The resulting linguistic characterizations provide the method for investigating the communication and interpretation as well as the essential concepts of the elements involved.

The need for further investigation on the relationships between actions and forms of communication was pioneered by Winograd and Florez (1986) in the computer science community. It is a research shift from the computation of forms of representation to the cognitive understanding of representations in order to communicate (Winograd 2006), which can be extended in interoperability in specific domains such as the AEC (Mutis and Issa 2007). The characterization represents an analysis of the problems of communication within syntactic forms of representation. This research, then, extends this analysis to the existing communication problem within interoperability. As was explained in the former section, communication problems such as misinterpretations of the forms of representation within interoperability need to be formally addressed. Communicating information embraces actions of exchanging, sharing, and interpreting information. The action of exchanging and of sharing involves additional rules that govern the communication activity. Communication is then a more general term that is used in this research for more specific actions such as the exchanging, sharing, and integration of information.

One of the results from the inclusion of the Speech Act Theory (Searle 1969)in this research is the claim that the interpreting action is an existing condition to fully perform an interoperability activity. In order to have a more comprehensive definition, this research proposes the concept of the interoperability act that defines the complete set of actions that produces the communication among construction project actors independently of the type of representation of the form. The understanding of the interoperability act provides an illustration of the elements that need to be included within the sequence of the actions involved within interoperability. Under the premise that human intervention is included and that it is characterized by the interpretation of information, the production of an effective communication from the source to the interpreter constitutes the set of actions of the interoperability act. To facilitate the explanation, simple syntactic forms of representation are employed. However, the actions involved within the exchanging of information within a workflow are not presented in this analysis. The purpose of this paper is to illustrate the interoperability-act concept in a simplified fashion.

3.1 SPEECH ACT

The Speech Act Theory provides a characterization of linguistic expressions. The speech act defines rule-governed forms of behavior when actors play a role in communicating information through language, specifically through the act of speaking. There are a set of sufficient and necessary conditions for the performance of particular speech acts where certain kinds of behavior, such as intentional behavior, can be characterized (Searle 1985). This analysis is a parallel to the governing rules, such as semantic rules, and the communication activities that takes place within interoperability.

The speech act characterizes what the speaker communicates to the hearer by relying on the mutually shared background of the information or contexts and the intention of the utterance (Searle 1969). In the simplest case, two actors, a speaker and a hearer, participate in a speech act. Thus, when there is an utterance within a communicative act, an understanding of the facts and relevance of the conversation, a setting up of the background information pertinent to the conversation, and assumptions and inferences are needed to capture the intended meaning within the expressed utterance.

In the case of the interpretation step as part of an interoperability activity, what is shared among the actors is not an utterance but a representation of concepts. Some actors are the ones that generate the information and others are the interpreters. In the speech act, there is the hearer and the speaker. It is easy to observe that actors are participants in a construction project, and the project is the environment where the motivated interactions of the actors take place. The actors who share the representations with other peers within the project have a predefined role. The concepts are translated into different forms of representation in order to semantically communicate them and suggest some actions for the interpreter. These actions are the result of the inferences and assumptions made by the interpreter.

The interpreters identify the intention on the representation generated by the sources and assert their meanings. The result of these assertions is the interpreters' commitment to actions on a particular activity. If it was not possible for the assertion to be executed in order to capture the representations' meanings, additional requisitions of information from the sources will be required.

Within the speech act, the hearer asserts and commits him or herself to an action or rejects the utterance in play when its intention was not captured. The speech act defines five categories within the illocutionary act. An illocutionary act is the entire speech act realized by an utterance, which contains elements of reference, predicate, and illocutionary force. The summarized categories, their explanation and illustration through the parallel with the interoperability act are as follows:

1. Assertive. The speaker tells the listener how the things are. When a representation is created by an actor, a set of conditions are included with it. The interpreter is able to fully identify those conditions from the shared or exchanged representation.
2. Directive. The speaker tries to get the listener to do something. The representation is created with the conditions to get a particular reaction from the interpreter or to force the interpreter to perform a specific action.
3. Commissive. The listener commits to do something after hearing the utterance. After interpreting the representation, the interpreter commits to perform some activity according to the course of action expressed in the representation. The representation has the ability to represent those courses of action.
4. Expressive. The speaker expresses attitudes to the listener. The interpreter captures the force from the representation. The force should indicate the manner of how the course of actions should be executed.
5. Declarative. The speaker brings changes in the world through the utterances. A representation contains expressions that demand changes through the reaction of the interpreter.

3.2 A UNIT OF ANALYSIS OF THE INTEROPERABILITY ACT

A parallel between interoperability and the Speech Act Theory brings about the opportunity to introduce the conceptual propositions of systems of communication. This research proposes a basic unit of analysis for performing interoperability acts based on Searle's Speech Act Theory work and of Lakoff and Johnson's metaphorical concepts (Lakoff and Johnson 1999; Lakoff and Johnson 2003).

When a speaker attempts to deliver a message to the listener the issuance of the utterance is composed of a set of words. However, as the Speech Act Theory advocates, it is misleading to understand that the unit of communication is words, symbols, sentences, or tokens. The unit of communication is the production or issuance of the tokens under particular conditions that characterize the speech act, such as rules of behavior. In interoperability, the unit of analysis will implicate the inclusion of conditions to produce the interoperability actions. As the vehicles or medium for communication of the illocutionary acts are symbols, words, or sentences, in interoperability, the mediums are forms of representations such as drawings or visual representations. However, in interoperability, the act of communicating meanings or semantics is not composed solely of the medium. The act has to be complemented with the conditions and behavior of the interoperability act. The interpreter has to identify the conditions and behavior that the actor who originates the representation requires.

The simplest case of the interoperability act is illustrated in Figure 2. The actor who generates a representation employs the representation as a medium to express or communicate semantics of a particular concept. An explanation of a situation within the set of construction specifications is a representation that is expressed by syntactic forms. The drawing of a metal door of a building is a visual representation expressed by a metaphor. The actor generates the representation with the intention that the interpreter understands the intended semantics. If the interpreter fully understands the semantic expressed within the representation, the interoperability act is fully performed. The interoperability act is reached when the interpreter understands the specific semantics of the representation. This is the minimum unit of analysis. The conditions and behavior expressed in the representation are similar to the ones expressed in the speech act. The minimum unit of analysis for the interoperability act embraces a particular communication of the meaning with similar conditions and behaviors of the speech act.

Figure 2 illustrates the case of when the actor who originates the representation attempts to construct the representation with the original, intended meaning. However when the representation is interpreted, the semantic can be captured by the interpreter. The representation expresses the semantics for the actor who generates the representation. If the interpreter cannot deduce the semantics from the representation, the interoperability act is not reached.

It is important to note that it is not a requirement for the actors to share the same space or synchronically and deliberately be arranged spatially for performing the interpretation within the interoperability activity, as they are both involved in the speech acts. Also, the direction of the movement of the illocutionary point is the same direction of the exchanged information destination.

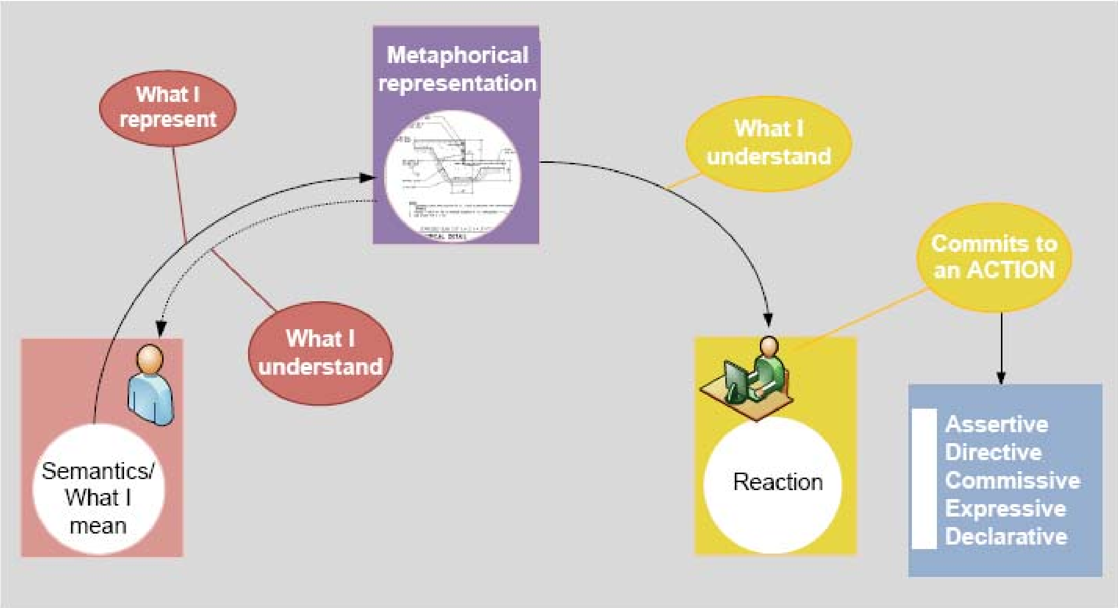

Figure 2. Interoperability Act

4. CONCLUSIONS

Since human intervention is required for interoperability, strategies to interpret the information that is exchanged, shared, and further integrated are required. Therefore, interoperability process demands human intervention and interpretations of an observed representation. The interpretation of a door represented by a series of lines in a CAD solution is an interoperability activity performed by an actor, or interpreter, who plays the role of a cognitive agent. The construction industry and institutional agencies have adopted strategies based on a consensus to approach problems due to a lack of interoperability. This research proposes that efforts should be focused on finding methods for "understanding" the information generated from other construction participants. Strategies for "understanding" what is to be added, processed, or manipulated should primarily be addressed. The study of the "understanding" involves the interpretations of the meanings of the manipulated information.

The research focuses on inquiries concerning how a construction participant sees the real world and how he or she maps the views of the world into representations that reflect these views. For this purpose, this research takes into account aspects concerning the nature of knowledge representation per se, the method for characterizing domain concepts into representations, and the act for interpreting concepts expressed in the generated representations by other actors.

The understanding of the interoperability act provides an illustration of the elements that need to be included within the sequence of the actions involved within interoperability. Under the premise that human intervention is included and that it is characterized by the interpretation of information, the production of an effective communication from the source to the interpreter constitutes the set of actions of the interoperability act. The analysis of the interoperability act is based on the Speech Act theory borrowed from the philosophy of language. This science has considerably advanced the understanding of effective communication and interpretation of representations. A close analysis will help the construction domain to reach answers on the interoperability paradigm. Under the research shift, our current research efforts addressed developing information processing strategies between two cognitive agents through the construction concept representations. The purpose is to study methods of communication through traditional forms of representation in construction by inquiring on their effects within interoperability.

REFERENCES

Amor, R., and Faraj, I. (2001). "Misconceptions about integrated project databases." ITcon, 6, 57-67. Anumba, C. J., Ugwu, O. O., and Ren, Z. (2005). Introduction In Chimay J. Anumba, O. O. Ugwu, and Z. Ren (Eds.), Agents and multi-agent systems in construction (pp. 1 - 6), Taylor & Francis. New York Bakis, N., Aouad, G., and Kagioglou, M. (2007). "Towards distributed product data sharing environments -- Progress so far and future challenges." Automation in Construction, 16(5), 586-595. Barresi, S., Rezgui, Y., Lima, C., and Meziane, F. (2008). Semantic Resources Integration and Interoperability in the Construction Domain In Yannis Manolopoulos, Joaquim Filipe, Panos Constantopoulos, and José Cordeiro (Eds.), Lecture Notes in Business Information Processing, 3 4,(pp. 336 - 347), Springer. Berlin C. Lima, C., Ferreira-da-Silva, C., and Le Duc, A. Z. (2005). "A framework to support interoperability among semantic resources." CSTB, Centre Scientifique et Technique du Batiment. Report12. Ducq, Y., Chen, D., and Vallespir, B. (2004). "Interoperability in enterprise modelling: requirements and roadmap." Advanced Engineering Informatics, 18(4), 193-203. El-Diraby, T. A., Lima, C., and Feis, B. (2005). "Domain taxonomy for construction concepts: Toward a formal ontology for construction knowledge." Journal of Computing in Civil Engineering, 19(4=), 394 - 406. Motta, E. (2000). "The Knowledge Modelling Paradigm In Knowledge Engineering." Handbook of Software Engineering and Knowledge Engineering Mutis, I., and Issa, R. (2007). "Conceptual role semantics for interpretation of construction industry concepts." 2007 ASCE International Workshop on Computing in Civil Engineering, Carnegie Mellon University. Pittsburgh, PA, 8 p. O'Brien, W. J., Issa, R. R. A., Hammer, J., Schmalz, M. S., Geunes, J., and Bai, S. X. (2002). "SEEK: Accomplishing enterprise information integration across heterogeneous sources." ITcon, 7, 101 - 123. 13
Partridge, C. (2002). "The role of ontology in integrating semantically heterogeneous databases." 05/02, National Research Council, Institute of Systems Theory and Biomedical Engineering. (LADSEB-CNR), Padova - Italy. Report24. Searle, J. R. (1969). Speech acts: An essay in the philosophy of language Cambridge University Press, Cambridge, UK. Taylor, J., and Levitt, R. (2004). "Inter-organizational knowledge flow and innovation diffusion in project-based industries ", Stanford University. Report Winograd, T. (2006). "Shifting viewpoints: Artificial intelligence and human--computer interaction." Artif. Intell., 170(18), 1256-1258. Winograd, T., and Florez, F. (1986). Understanding computers and cognition: A new foundation for design Addison-Wesley Professional.