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Ontological Approach

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Design and Management of Transactions in the AEC/FM Industry Using an Ontological Approach

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Abstract: In the AEC/FM industry, partners must frequently exchange information to accomplish a wide range of collaborative tasks. While this exchange of information is typically manual or human-to-human communication, there is an ongoing trend towards automated or semi-automated communications, where the communication is directly from computer-to-computer. In order to accomplish this computer-based communication, message-based communications (referred to as transactions) must be more formally described and designed. This research looks at the way that message-based communications between project partners are defined and carried out, with a goal of formalizing these messages to support computer-based transactions. The work proposes an ontology-based approach to formalizing messages in the domain of infrastructure management. The research has also carried out an industry survey to identify current practices for information exchange in the domain of infrastructure management, and to determine opportunities for improvement. Based on the results of this survey, the ontology-based approach will be used to develop a procedure for improving computer-based information exchange practices.

1. Introduction

More than most industries, the Architectural, Engineering, Construction, and Facility Management (AEC/FM) industry is inherently fragmented and multi-disciplinary. Various AEC/FM organizations join hands to accomplish projects in a collaborative manner. As part of the collaborative effort, large volumes of information created by various participants are required to be exchanged in an efficient way between the parties. As information systems continue to evolve, these information exchanges increasingly involve data exchanges between different stakeholders' computer applications. An unresolved challenge facing government agencies, contractor organization, consulting firms, architects, private and public associations, and private agencies in the AEC/FM industry, is the issue of how best to carry out and manage these electronic information exchanges.

Presently, information is exchanged between collaborating partners in manual, unstructured and ad hoc ways, leading to ineffective and poor communication in the AEC/FM industry. Ineffective communication leads to time and cost overrun, productivity losses, rework, and reduced quality. Emerging trends in the AEC/FM industry for globalization and partnering combined with enhanced pressure to reduce project time and cost, require effective and efficient exchange of information. This emphasizes the need to structure information and formalize information flows to enable electronic communication and ensure consistent and timely exchange of information between information systems of public infrastructure organizations of the AEC/FM industry. The term "communication process" is referred to a transaction in this research.

For a wide range of information systems from different organizations to talk to each other, information relating to AEC/FM processes and messages should be represented in a neutral computer interpretable format – an ontology. Ontologies represent shared understanding of how things exist in the real world; they provide consistent semantics and definitions of the AEC/FM communication processes and messages to achieve interoperability of the information systems. Therefore, this research has created a set of Ontologies to support digital AEC/FM communications. This paper describes the creation, evaluation and application of a central component of this work, the Transaction Domain Ontology (Trans_Dom_Onto) for transaction design and management in the domain of infrastructure management. This paper is divided into five sections; (i) a brief description of relevant research work; (ii) a transaction formalism framework; (iii) A description of the development the Trans_Dom_Onto; (iv) a discussion of the potential application areas in infrastructure management; and (v) conclusions.

2. Previous Research

Relevant work that forms the basis for this research is divided into two dimensions: state-of-the-art process formalism methodologies and ontology development in infrastructure management.

2.1 State-of-the-Art Process Formalism Methodologies and Standards

Some of the relevant process formalism initiatives in the AEC/FM industry are as follows:

2.1.1 Information Delivery Manual (IDM)

The Information Delivery Manual (IDM) is a requirement specification methodology developed by the International Alliance of Interoperability (IAI)/BuildingSMART in conjunction with the Industry Foundation Classes (IFCs), with the main objective to formalize information exchange processes in the building sector of the construction industry. Recently, some limited work has also been initiated in the area of infrastructure asset inventory and facility management during the operation and maintenance stage of the project, (IAI-IDM, 2009). The focus is on the exchange of IFC building information models, it does not support non-IFC data exchange, and much of the information that can be used to fully describe formal transactions are not defined in either the IFC data standards or the IDM methodology. Thus, while many aspects of the IDM are useful for proving a methodology for formalizing information exchange, we must replace the IFC-specific aspects of the IDM with ontologies that are targeted to transactions in the infrastructure management domain.

2.1.2 Model View Definition (MVD)

The Model-View Definition (MVD) format is a harmonized aggregation of formats and approaches developed by the Building Life Cycle Interoperable, (BLIS co-ordination project), Product Model Data in the Construction Process, (ProIT Project in Finland), IDM (IAI Norwegian Chapter) and IFC implementation group's Model View Definition Group. The main goal of the standard goal is to implement IFCs at the software level efficiently, (IAI-MVD, 2005). The standard has a narrow scope in terms of formalizing a process for IFC Model View Definition, and it depends on the IDM for requirement specification. As such, it is not a good fit for our focus where diversified AEC/FM processes are formalized and exchange requirements (ERs) are captured.

2.1.3 Voorwaarden Scheppen Voor Invoering Standaardisatie, (VISI)

The Dutch "Voorwaarden Scheppen Voor Invoering Standaardisatie ICT in de GWW-sector" (VISI), or "Creating Conditions for Introducing Standardization of Information & Communication Technology in Civil Engineering", (VISI, 2007) is an open standard for communication management developed by CROW, CUR and SBR, representing numerous organizations in GWW and B&U sectors. The main objective of the standard is to standardize communication between partners at the transaction and template levels employing action-based communication theory, (VISI, 2007). The standard does provide a comprehensive mechanism to capture agreements on generic process maps and exchange requirements. Also, the standard and project specific frameworks are constructed with local focus, i.e., in the context of Dutch construction industry, which may vary significantly across geographic regions.

Moreover, it does not support any data/information or knowledge model (ontology) for the interoperability of diversified infrastructure information systems.

2.1.4 Construction Objects and the Integration of Processes and Systems (COINS)

The COINS Engineering Method (CEM) and COINS Building Information Model (CBIM), are a Dutch open standard developed and published by the CUR management organization. Its' primary objective is to achieve life cycle integration and to formalize processes in the building sector; however, some work in infrastructure management has also been initiated recently to improve communication between partners (Schaap et al. 2008). The focus of the standard is on a local context, i.e. the Dutch construction industry; as such, application of the CBIM across an international AEC/FM industry would require adjustments. Also, the standard focuses on 3D object-based exchange of information rather than template-based exchange of information. Moreover, the development steps are not elaborated, making it difficult to apply this methodology to the formalization of information exchange processes.

2.2 Related Work in the Area of Ontology Development

One of the most common definitions of Ontology is an “explicit formal specification of the terms in the domain and the relations among them”, (Gruber, 1995). According to Gomez-Perez et al (2005), ontologies are constructed in a layered architecture at various levels of abstraction: *Upper Ontologies* define the most generic, universal concepts that provide the starting points for the more specific concepts in the lower-level Ontologies; *Domain Ontologies* define the terms and concepts that are common throughout the area of application and may be shared by different software applications; *Application Ontologies* define information that is specific to a particular application or information system; and *User Ontologies* that further refine the concepts as they relate to a specific user or data set. This layered architecture has been applied to this research work.

2.2.1 Ontologies in the Area of Infrastructure Management

This research builds upon previous related research that developed a series of ontologies in the domain of infrastructure management encompassing the infrastructure *products*, *processes* and *actors*. The *Infrastructure Product Ontology (IPD-Onto)* represents knowledge about physical products in diversified infrastructure sectors including; water, wastewater, electrical, telecommunication and gas, (El-Diraby, 2006), whereas the *Infrastructure and Construction Process Ontology (IC-Pro-Onto)* represents knowledge about the processes over the life cycle of the projects in the infrastructure sector (El-Gohary, 2008) and the *Actor Ontology (Actor-Onto)* captures knowledge about the actors and their roles during design, implementation and management of infrastructure (Zhang & El-Diraby, 2009). To manage infrastructure assets, collaboration partners depend on each other for information to accomplish processes (IC-Pro-Onto) successfully. Therefore, it is important for the actors (Actor-Onto) to exchange information (IPD-Onto) effectively and efficiently. While the core formalism dimensions are complete, there remains a need to formalize information exchange processes (transactions) to enable computer-to-computer message-based exchange of information. Transaction formalism involves specifying and defining; (i) the communication process and the sequence of the individual message (IC-Pro-Onto – How); (ii) the information required in a transaction (IPD-Onto - What); and (iii) actor role responsible for the exchange of information (Actor-Onto - Who). The gap that remains in the infrastructure knowledge representation is the specification of information exchange details, which is to be addressed through the development of the Transaction Ontology, Trans_Dom_Onto.

3. Transaction Upper Ontology

As introduced previously, the highest level in overall ontology architecture is the upper ontology. In this research, we have defined a *Transaction Upper Ontology, Trans_Upper_Onto*, derived largely from the upper ontologies of the previously introduced infrastructure ontologies. Figure 1 shows the Trans_Upper_Onto, a modified version of the Upper Ontology proposed by Osman (2007), El-Gohary (2008), and Zhang and El-Diraby (2009), in the domain of public infrastructure. The Trans_Upper_Onto is organized into core-concept and support-concept. The core concepts represent all the key generic concepts that form the basis of the transaction domain knowledge. The core concepts include: project,

action, product and resources, characterized by trans-industry generality (which means that the knowledge is so generic that it is applicable to a range of industries). According to Fox and Grüninger (1998), these concepts are the key entities in the production and services systems and manufacturing systems. The support concepts support modeling, organization, classification, and definition of the core concepts, including; attribute, modality, mechanism, constraint, and relationship. A brief introduction of these concepts follows.

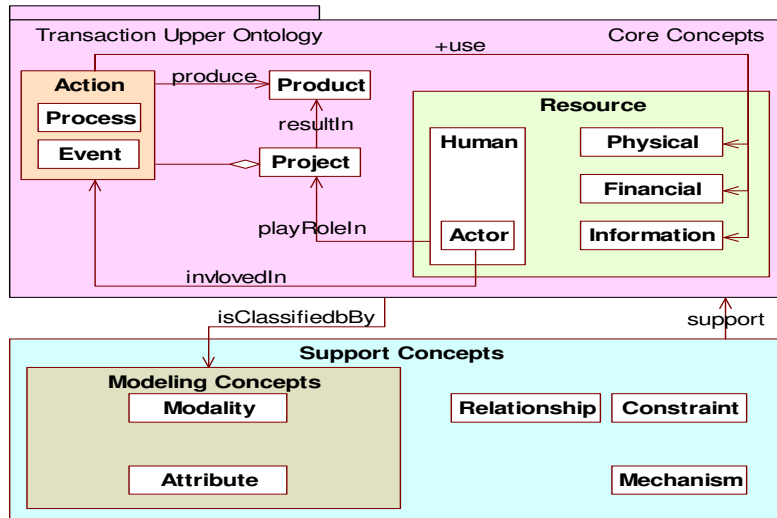


Figure 1: Transaction Upper Ontology

3.1.1 Core-Concepts

The core concepts presented in Figure 1 are described in the context of a specific project, where project is defined as “a temporary endeavor undertaken to create unique products, services, or result” (PMI, 2008). “Actor” is a human resource that plays diversified roles and performs a variety of actions, where action is an umbrella concept representing processes and events, according to El-Gohary (2008). According to Becker et al. (1997) “process models are images of the logical and temporal order of functions.” Therefore, these concepts are characterized and differentiated by the temporal scale. A process captures a set of activities that are undertaken to accomplish an objective over a period of time. An event, on the other hand, refers to the instantaneous occurrence of an activity (e.g., atomic transactions), where an instantaneous transfer of information from one role to another takes place. The execution of the action (process & event) in the project produces a product, which is classified as “knowledge, knowledge item, physical product, and decision”, (Osman, 2007). The actor roles use resources to produce a product. The resource is something of value and is scarce, which includes physical resource (equipment, material, etc.), informational resource (software, drawing, contract, etc.), human resource (administrative and professional staff, skilled/unskilled workers etc.), and financial (owner’s equity, loan from the bank, etc.).

3.1.2 Support-Concepts

Support concepts support the core concepts in relation to taxonomy development and establishing the relationships between the core concepts. These include, (i) modeling concepts (attribute and modality), (ii) mechanism, (iii) constraint, (iv) relationship, and (v) axiom. The modeling concepts support concept classification, whereas the mechanism, constraint, and relationship concepts enrich knowledge representation. An attribute is a characteristic, feature or property that describes a thing, entity or concept; whereas modality refers to a specific perspective or dimension through which a concept or entity is viewed and classified. Modality is defined as a characteristic that describes a thing and denotes its belonging to a particular group or category, (Osman, 2007 and El-Gohary, 2008). Modality brings multi-dimensionality to the knowledge. The concept of the modality is used in Trans_Dom_Onto to ease

categorization, management, and organization of the transaction concepts. Transactions are categorized based on two main modalities: *transaction communication modality* and *transaction domain modality*. The communication modality classifies transaction based on how transaction is communicated between collaboration partners. For instance, pattern based transaction and channel based transaction are two views or modalities of transaction classification based on communication. Domain transaction modality classifies transaction based on different domains. For instance, sector transaction is a specific view or modality of transaction classification based on domain. According to Osman (2007) and El-Gohary (2008), mechanism is an “umbrella concept representing guides, methods, and measures”, which are extended to capture knowledge pertaining to the diversified mechanisms required to enable electronic transactions. Mechanisms are the means through which actor roles exchange information between each other. Constraint is a situation, circumstance, state, and/or obligation that limit the freedom of an action. According to Osman (2007), axioms specify definition of the concepts and constraint on their interpretation, whereas relationships are the associations between the concepts in the form of “is-a” or “part-of/composed-of” to enrich the knowledge representation.

4. Transaction Domain Ontology

Having introduced the Trans_Upper_Onto, the following is a description of the development of a domain ontology for transactions in the public infrastructure sector, the Trans_Dom_Onto. A ten-step methodology has been devised to build Trans_Dom_Onto, which is a hybrid version of the various methodologies developed by: (i) Fernandez-Lopez et al. (1997) – the METHONTOLOGY; (ii) Uschold and Gruininger (1996); and Noy and McGuinness (2001). The ten-step approach to develop the Tran_Dom_Onto; including (i) define ontology coverage definition; (ii) capture competency questions; (iii) generate taxonomy; (iv) reuse existing ontology; (v) develop transaction domain kernel ontology – (Trans_Dom_Kernel_Onto); (vi) extend transaction domain kernel ontology; (vii) capture ontology; (viii) code ontology; (ix) evaluate ontology; and (x) document ontology.

4.1.1 Define Ontology Coverage – (Step 1)

This step defines the coverage of Trans_Dom_Onto in terms of its purpose, usability, and scope. Its purpose is to capture and represent transaction domain knowledge in the AEC/FM industry—specifically in the infrastructure sector—to enable message-based exchange of information between collaborating partners. The intended use of the Trans_Dom_Onto is to provide a foundation of common concept definitions for future extensions as deemed necessary for creating application-level ontologies in support of specific software development efforts. The primary users of the Trans_Dom_Onto are the software developers who will use the ontology to build transaction systems to support collaboration of the end users including; project-related partners, supply chain organizations in the construction industry, agencies like utility, government/non-governmental organizations and general users.

4.1.2 Capture Competency Questions – (Step 2)

The competency questions represent a set of requirements developed through requirement analysis of the state-of-the-art standards, ontologies and process models. According to Gruninger and Fox (1995), these requirements guide formulation of the competency questions, which the ontology should be able to answer. All competency questions are not presented in this paper due to space limitation; however a set of the competency questions relating to transaction are as follows; (i) what are the different types of AEC/FM transactions based on the means of transmission?; (ii) how is access to the transaction is controlled?; and (iii) what are the design patterns of the AEC/FM transactions?.

4.1.3 Generate Taxonomy - (Step 3)

In this step, preliminary transaction taxonomy has been generated using three steps: (i) concepts were captured from state-of-the-art standards, ontologies and models; (ii) concepts were compared and identified synonymous concepts to avoid duplication; and (iii) a preliminary categorization of the concepts was developed.

4.1.4 Reuse Existing Ontologies - (Step 4)

During the Trans_Dom_Onto development, use has made of the existing ontologies in the domain of infrastructure. The term “use” here refers to establishing links between existing and new ontologies, in contrast to merging some of all of an existing ontology. Therefore, a link has been established between Trans_Dom_Onto and three infrastructure ontologies described in section 2.2.1. in order to re-use the concepts that have already been adequately defined there.

4.1.5 Develop Transaction Domain Kernel Ontology, Trans_Dom_Kernel_Onto – (Step 5)

The Trans_Dom_Onto, as a domain Ontology constructed using the concepts defined in the upper ontology, has been further decomposed into a central kernel domain ontology along with a series of extension domain Ontologies. The purpose of the *Transaction Domain Kernel Ontology, Trans-Dom-Kernel-Onto*, is to capture a lean structure to represent a holistic view of the transaction domain knowledge, enhance comprehension, ease concept extensions and better organize the knowledge. Similar to the Trans-Upper-Onto, the knowledge in the kernel domain ontology is also organized into core-concept and support-concept, as shown in Figure 2.

4.1.5.1 Transaction Domain Kernel Ontology, Core-Concepts

The actor, actor–role, message, information and transaction classes constitute the core concepts in the kernel ontology. In any given information exchange process, an actor participates in a transaction and plays stakeholder and transaction roles. Actor-roles possess and control information, which they need to share or transfer in a transaction. Content and context information are two types of information that are represented in either tangible (written) or intangible (verbal) form commonly known as a message, which is part of a transaction and is transmitted between the actor-roles in a given transaction. The name of the actor is reflected in a message instance whereas the name of the actor-role is reflected in a message. The definitions of the core concepts are as follows:

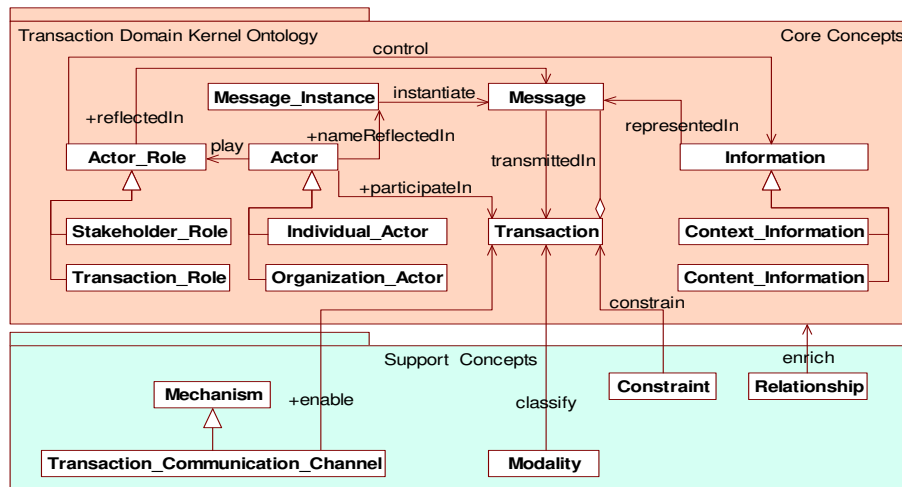


Figure 2: Transaction Domain Kernel Ontology

An actor can be one of two types: an individual (a human being, considered to be an indivisible entity), or an organization (a unique framework of authority within which persons act towards achieving overall common objectives) (ISO, 2006). An Actor-role is defined as “a set of connected behaviours and attributes as conceptualized by actors in a given social position”, (Zhang & El-Diraby, 2009). In the Trans_Dom_Onto, actor-role has two types: stakeholder role (the role an actor plays by virtue of their position in a social context) and a transaction role (the roles actor play in exchanging information in a transaction, i.e. sender or receiver role). Information is defined as data (a series of atomic and disconnected facts, statement of events or observation), processed, analyzed and co-related to a context to make it useful for the user. It is represented in a message formulated in tangible (written) or intangible (verbal and non-verbal) forms that are exchanged between collaborating partners, whereas a message instance is an instantaneous message accomplished in a given transaction. According to Pouria et al.

(2002), any exchange of information; “communication or interaction between different parties that make up the information flow can be described as a transaction”. In this research work, transaction is defined as “any communication or interaction between the sender and receiver roles that make up the information flow through a single or collection of a sequenced set of messages”.

4.1.5.2 Transaction Domain Kernel Ontology, Support-Concepts

The support concepts encompass modality, mechanism, constraint, and relationship at a higher level of abstraction. To maintain the lean structure of the kernel ontology, concepts like attributes and axioms are off loaded. Relationships between core and support abstract concepts are established as described below. Modality classifies a concept from a specific perspective (Osman, 2007). In this research work, transactions are classified based on two main modalities: transaction communication modality (which groups transaction modalities related to communication, i.e., how transactions are executed between partners), and transaction domain modality (which groups transaction modalities based on diversified application domains).

Mechanism refers to a transaction communication channel that an actor-role uses to accomplish a transaction. A channel is a means of communication that enables the transmission of messages between the actor-roles. Constraint is a situation, circumstance, state, and/or obligation that limit the freedom of an action in terms of transaction design and implementation. According to Osman (2007), relationships are the associations between the concepts to enrich knowledge representation,

4.1.6 Extend Transaction Domain Kernel Ontology – (STEP 6)

The core and support concepts shown in the transaction domain kernel ontology are extended to develop detailed taxonomies. The taxonomy of the transaction concept is created based on communication and domain modalities. Transaction taxonomy based on transaction communication modality includes; pattern based transaction, business transaction, interface based transaction, control based transaction, channel based transaction, and actor role centered transaction. Moreover, transaction taxonomy based on transaction domain modality includes; bilateral and multilateral transaction, sector transaction, and project service delivery transaction. Actor and actor role taxonomy is developed based on stakeholder and transaction roles. Message taxonomy represents functional message, formational message, representational message, and intelligent message. Information taxonomy is developed based on content information and context information. Similarly, support concepts are extended to develop detailed taxonomies of the support concepts. Due to space limitation, detailed taxonomies of the core and support concepts are not presented.

4.1.7 Capture Ontology – (Step 7)

Ontology capturing is the specification and formulation of axioms in the ontology. According to El-Gohary (2008), Osman (2007), and Gruninger and Fox (1995), axioms unambiguously define the concepts in the ontology and constraints on their interpretation. Axioms in Trans_Dom_Onto are classified as soft axioms (which describe concepts in plain English) and hard axioms (which describe concepts in formal language: the Web Ontology Language (OWL) - Description Logic Syntax (DL). In Trans_Dom_Onto, hard axioms are of three types, disjoint axiom, subsumption /is-a axiom and property restriction axioms including, existential, universal and cardinality restrictions. Hard axioms in terms of property restriction for some of the concepts presented in the kernel ontology as follows:

Actor:	∃ play Actor_Role	play some Actor_Role
Actor_Role:	∃ reflectedIn Message	reflectedIn some Message
	∃ control Information	control some Information
Information:	∃ representedIn Message	representedIn some Message
Message:	∃ represent Information	represent some Information
Transaction:	∃ exchange Information	exchange some Information.

4.1.8 Code Ontology – (Step 8)

First, abstract transaction domain knowledge (the kernel ontology) was modeled at the conceptual level using the Unified Modelling Language (UML) as shown in Figure 3. Second, it has formally represented and coded using the knowledge representation language, Web Ontology Language (OWL), which was chosen for its’ robustness and richness in providing more facilities to express concept semantics and

represent machine-interpretable content on the web than other languages like XML, RDF and RDF-S. For this purpose, Protégé 4.0.2, an OWL-based open-source ontology editor (Protégé, 2011) was used to code and represent the transaction domain knowledge as shown in Figure 3(a).

4.1.9 Evaluate Ontology - (Step 9)

According to Gomez-Perez (1996 and 2001), evaluation refers to judging the content of the ontology with respect to some frame of reference, such as a set of requirements, competency questions (defined as ontology verification) and the real world model of the domain (defined as ontology validation). The Trans_Dom_Onto verification has been completed, and validation is underway. The proposed verification criteria includes: consistency (to measure circulatory errors, partition errors, and semantic inconsistency error); conciseness (to measure grammatical redundancy errors, identical formal definition of some classes); and completeness (to measure incomplete concept classification and partition errors). Verification tools used to satisfy the criteria includes: automated description logic Reasoners in Protege 4.0.2, such as FaCT++, Pellet and RacerPro 2 as shown in Figure 3(b) and competency questions presented in step 2. These Reasoners have run to automatically check the content of the ontology for consistency, conciseness and completeness. The reasoning analysis result shown in Figure 3(c) reflects the term “Nothing”, under the inferred class hierarchy (an automatically generated class hierarchy), describes a superclass of things having subclasses of concepts with any one of the errors mentioned above. No class has been identified in the inferred class hierarchy that is inconsistent as there are no subclasses found under the superclass “Nothing”, which shows that the Trans_Dom_Onto is consistent and concise. Competency question-based verification involves evaluating the content of the ontology based on the competency questions developed in step 2. The criteria and measure to verify each competency question includes: consistency (semantic inconsistency errors); completeness (incomplete concept classification); and correctness (identity – real world class identification error). Based on these measures, each competency question has checked manually.

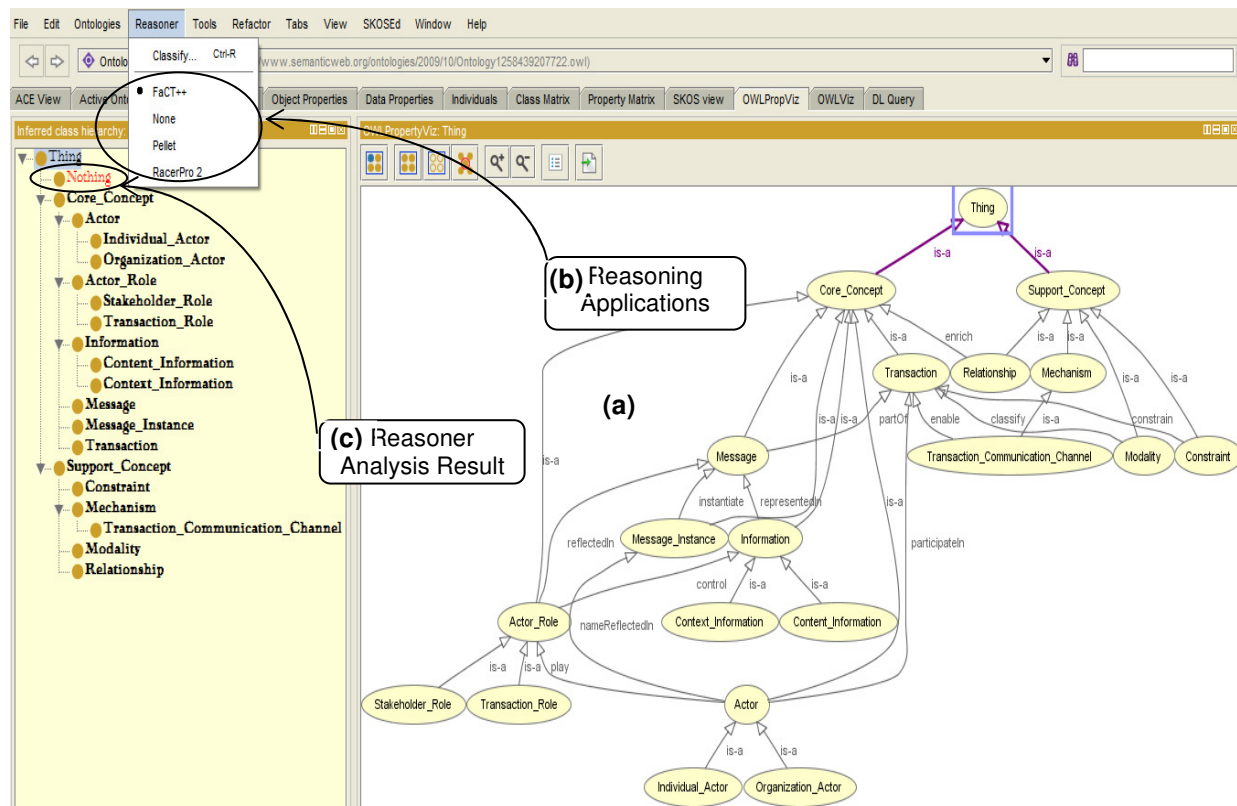


Figure 3: (a) Ontology Coding and Visualization (b) Reasoning Application; (c) Reasoner Analysis Result

The results of the competency question-based verification indicates that the ontology was 100% free of semantic inconsistency errors, since none of the classes were found to have these errors. Moreover, for incomplete concept classification errors, 79% of the classes found to be error-free while 21% had partial errors. The reason for partial errors was due to dependence on other infrastructure ontologies (Product, Process and Actor ontology), providing some of these concepts during formalization of transaction messages that are beyond the scope of the Trans_Dom_Onto. Also, competency questions were verified for identity errors and found to be 79% error-free, 18% partial errors, and 2% errors. These results show satisfactory compliance with competency questions.

4.1.10 Document Ontology – (Step 10)

The Trans_Dom_Onto has been documented in this step in a format that facilitates its future use.

5. Transaction Domain Ontology Area of Application

The intent of this research is to apply the Tran_Dom_Onto to formalize messages in a number of transactions in the infrastructure sector that have the greatest potential to IT improvement. For this purpose, an IT survey of the municipalities is being conducted to identify information exchanges that are in the process of computerization, and that are suitable for formalization. One of the potential processes identified in the municipal infrastructure management is the reporting process between Public Sector Accounting Board of the federal government and the municipalities for the exchange of asset inventory and worth information. These identified transactions are to be defined with the help of experts during the interview survey in terms of; (i) specifying the numbers of atomic transactions (individual messages between the transaction roles, i.e. sender and receiver role) and their choreography (sequence); (ii) information (in terms of exchange requirements); (iii) and the actor roles that are responsible for the exchange of information. The requirements captured from the experts will be used towards message formalism.

6. Conclusions

A transaction ontology has been developed in the infrastructure sector of the AEC/FM industry to support formalism of communication processes (transactions). The transaction ontology was created at two levels of abstraction: a Transaction Upper Ontology and a Transaction Domain Ontology. The Trans_Dom_Onto has been created using a ten step procedure developed from the amalgam of a number of state-of-the-art ontology engineering methodologies. Ontology verification has been used for evaluation; including Protege automated reasoners and competency questions. The transaction ontology will be applied to certain transactions in the area of infrastructure management that are being identified as having the greatest potential for IT improvement. The next steps in this ongoing research is to develop standard transaction models of the communication processes identified during the expert interview survey to accomplish formalism at the process level.

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8. References

Becker, J.; Rosemann, M.; and Schütte, R. 1997. "Business-to-Business Process Integration: Functions and Methods." *Proceedings of the 5th European Conference on Information Systems (ECIS'97)*, Cork, Ireland, UK: 816-827.

- El-Diraby, T. E. (2006). "Infrastructure Development in the Knowledge City" Lecture Notes in Computer Science, v 4200 LNAI, Intelligent Computing in Engineering and Architecture - 13th EG-ICE Workshop, ASCONA, Switzerland: 175-185.
- El-Gohary, N. 2008. "Semantic Process Modelling and Integration for Collaborative Construction and Infrastructure Development", PhD Thesis, Department of Civil Engineering, University of Toronto, Canada.
- Fernández López, M. ; Gómez-Pérez, A .; and Juristo N. 1997. "METHONTOLOGY: From Ontological Art to Ontological Engineering", *Spring Symposium on Ontological Engineering of AAAI*, Stanford University, California, USA: 33-40.
- Fox, M.S. and Gruninger, M. 1998. "Enterprise Modeling", *AI Magazine*, AAAI Press: 109-121.
- Gómez-Pérez, A , Lopez, F.P. and Corcho, O. 2005. "Ontological Engineering: with Examples from the Areas of Knowledge Management, E-commerce and the Semantic Web", *Advanced Information and Knowledge Processing*, Springer-Verlag London Limited.
- Gómez-Pérez, A. 1996. "Towards a Framework to Verify Knowledge Sharing Technology", *Expert Systems with Applications*, Vol. 11, No. 4: 519-529.
- Gómez-Pérez, A. 2001. "Evaluation of Ontologies", *International Journal of Intelligent Systems*, Vol. 16: 391-409.
- Gruber, T. R. (1995). "Towards Principles for the Design of Ontologies Used for Knowledge Sharing", *International Journal Human-Computer Studies*, Vol. 43, Academic Press Limited: 907-928
- Gruninger, M. and Fox, M.S. 1995, "Methodology for the Design and Evaluation of Ontologies", *Workshop on Basic Ontological Issues in Knowledge Sharing*, IJCAI-95, Montreal, Canada.
- IAI-IDM. 2009. "Information Delivery Manual", International Alliance for Interoperability, buildingSMART Norway. <http://www.iai.no/idm/>. <accessed April 2011>
- IAI-MVD. 2005. "Model View Definition", International Alliance of Interoperability, buildingSMART International, IFC Solution Factory, The Model View Definition Site. <http://www.blis-project.org/IAI-MVD/>. <accessed April 2011>
- International Organization for Standardization (ISO). 2006. "Information Technology - Business Agreement Semantic Descriptive Techniques", Part 4: Open-edi Business Transaction Ontology, International Organization for Standardization (ISO/IEC 15944-4).
- Noy, N. F. and McGuinness, D. L. 2001. "Ontology Development 101: A Guide to Creating Your First Ontology", Technical Report, KSL-01-05, Knowledge Systems, AI Laboratory, Stanford University.
- Osman, H. M. 2007. "A Knowledge-Enabled System for Routing Urban Utility Infrastructure", Ph. D. Thesis, Department of Civil engineering, University of Toronto, Canada.
- PMI. 2008. "A Guide to the Project Management Body of Knowledge", *PMBOK Guide - Fourth Edition*, Project Management Institute, An American National Standard, ANSI/PMI/99-001-2008.
- Pouria, A.; Halfawy, M.; and Froese, T. 2002. "Developing AEC/FM Transaction Standards", 3rd *International Conference on Concurrent Engineering in Construction*, University of California, Berkeley, USA: 99-108.
- Protégé. 2011. Protégé is a National Resource for Biomedical Ontologies and Knowledge, developed by the Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine. <http://protege.stanford.edu>. <accessed April 2011).
- Schaap, H. A., Bouwman, J.W., and Willems, P.H., 2008. "The COINS Systems", Concept Publication, CUR-Report 208-3, CUR Construction & Infrastructure.
- Uschold, M. and Gruninger. M. 1996. "Ontologies: Principles, Methods and Applications", *Knowledge Engineering Review*, AIAI-TR-191, Vol 11.
- VISI. 2007. "Voorwaarden Scheppen Voor Invoering Standaardisatie", Dutch Communication Management Standard, CROW - VISI Organization. <http://www.crow.nl/engels/>. <accessed April 2011>
- Zhang, J. and El-Diraby, T. E. 2009. "SSWP: A Social Semantic Web Portal for Effective Communication in Construction", *Journal of Computers*, Vol. 4(4), © 2009 Academy Publisher.