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Improving Representational Analysis:
An Example from the Enterprise Systems Interoperability Domain

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Abstract

Representational analysis is increasing in popularity, not just in the area of evaluation of conceptual modelling grammars, but in any real-world modelling situation where semantics are being communicated through the use of grammatical constructs or symbols. However, critical questions remain as to choosing the appropriate reference ontology as a representational benchmark for a given situation and applying that ontology analytically in the process of representational analysis. This paper demonstrates how meta-models of proposed reference ontologies can be compared and evaluated on the bases of equivalence, structure and scope in order to aid the selection task. Having selected the reference ontology, this paper explains the current practice of representational analysis and clearly delineates the limitations of the procedure at the input, process and output stages. Finally, this paper explains how an improved version of the representational analytical methodology can be used to establish the 'common' set of requirements for full enterprise systems interoperability – an application domain well outside that of traditional conceptual modelling.

Keywords

Representational analysis, ontology, BWW model, representation theory

POPULARITY OF REPRESENTATIONAL ANALYSES

As techniques for conceptual modelling, enterprise modelling, and business process modelling have proliferated over the years, researchers and practitioners have attempted to determine objective bases on which to compare, evaluate, and determine when to use these different techniques. Wand and Weber (1989; 1990; 1993; 1995) have investigated the branch of philosophy known as ontology as a foundation for understanding the process in developing an information system. Ontology is a well-established theoretical domain within philosophy that deals with identifying and understanding elements of the real world (Bunge, 2003). Wand and Weber adopted an ontology defined by Bunge (1977; 1979) and from this derived a model of representation for the Information Systems discipline that became widely known as the Bunge-Wand-Weber (BWW) representation model.

The process of using a model of representation based on a reference ontology, such as the Bunge-Wand-Weber representation model, as a type of benchmark for the evaluation of the representational capabilities of a modelling technique forms the core of the research method of *representational analysis*. In this process, the constructs of the chosen reference ontology are compared with the constructs of the target technique under analysis. The basic assumption is that any deviation from a 1-1 relationship between the corresponding constructs in the selected reference ontology and the target technique leads to a situation of representational deficiency and/or ambiguity in the use of the language, potentially causing confusion to end users. Such situations are classified as theoretical, *i.e.*, potential, representational shortcomings. These undesirable situations can be further categorized into the following four types (Weber, 1997):

- *construct overload* describes a situation in which a construct in the target technique represents two or more reference ontology constructs (m:1 relationship),
- *construct redundancy* describes a situation in which one construct in the reference ontology is depicted by two or more constructs in the target technique (1:m relationship),

- *construct excess* describes a situation in which at least one construct in the target technique does not map to any construct in the reference ontology (0:1 relationship), and
- *construct deficit* describes a situation in which at least one construct in the reference ontology does not map to any construct in the target technique (1:0 relationship).

Based on these four types of deficiency, representation analysis advocates the principle that a 'good' modelling technique should be *ontologically complete, i.e.,* it should not exhibit construct deficit. Ontological completeness implies that technique users can describe *all* real-world phenomena that they seek to have represented by the information system they model. A 'good' modelling technique should furthermore be *ontologically clear, i.e.,* it should not exhibit construct overload, redundancy or excess. Ontological clarity implies that users can *unambiguously* describe the real-world phenomena that they seek to have represented without causing confusion to the end users.

While previous research projects have shown that reference ontologies are a fruitful theoretical basis on which to perform such analyses (see, for example, (Recker *et al.*, 2006)), the question remains: which reference ontology to use? Like the BWW representation model that is based on Bunge's (1977; 1979) ontology, Milton and Kazmierczak (2000; 2004) have shown the usefulness of Chisholm's (1996) common-sense ontology as a basis for evaluating conceptual modelling techniques. Irrespective of the reference ontology employed, the actual process of performing the representational analysis remains problematic. The current process is open to the individual interpretations of the researchers who undertake the analysis. Consequently, such analyses are criticised as being subjective, *ad hoc*, and lacking in relevance. There is a need, therefore, for the systematic identification of shortcomings of the current analysis process. The identification of such weaknesses, and their subsequent mitigation, will lead to a more rigorous, objective and replicable analytical process.

Accordingly, this paper has several objectives. First, we suggest a meta-model based approach to examining and comparing reference ontologies with a view of selecting a reference ontology most appropriate to the intended modelling technique for analysis. Second, we aim to identify the shortcomings in the wider practice of representational analysis. The identification of such shortcomings will provide a basis upon which the practice of representational analysis can be improved. Finally, we provide a representational analysis of the overlap amongst several candidate interoperability standards, such as ebXML and BPEL, as an example of improved representational analyses and the wide application of representation models in general.

The remainder of this paper is structured as follows. The next section provides a brief overview of some of the recent related work. Section three overviews the use of meta-models to compare representation benchmarks such as the BWW representation model and Chisholm's ontology. Then, we summarise eight current shortcomings of representational analyses that are classified with respect to the three phases of analysis, *viz.,* input, process and output. The fifth section provides a description of an improved methodology for representational analysis and briefly discusses some results of the overlap amongst several candidate interoperability standards. The final section provides a brief summary of this work and outlines future research in this area.

RELATED WORK

The popularity of using reference ontologies, or representation models derived from reference ontologies, as a basis for the analysis of techniques that purport to assist analysts to develop models that emulate portions of the real world has been growing steadily. The Bunge-Wand-Weber representation model (Weber, 1997), for example, has been applied extensively in the context of the analysis of various modelling techniques. Wand and Weber (1989; 1993; 1995) and Weber (1997) have applied the BWW representation model to the 'classical' descriptions of entity-relationship (ER) modelling and logical data flow diagramming (LDFD). Weber and Zhang (1996) also examined the Nijssen Information Analysis Method (NIAM) using the BWW representation model. Green (1997) extended the work of Weber and Zhang (1996) and Wand and Weber (1993; 1995) by analysing various modelling techniques as they have been extended and implemented in upper CASE tools. Furthermore, Parsons and Wand (1997) proposed an initial model of objects and they use the BWW representation model to identify representation-oriented characteristics of objects. Along similar lines, Opdahl and Henderson-Sellers (2001) have used the BWW representation model to examine the individual modelling constructs within the OPEN Modelling Language (OML) version 1.1 based on 'conventional' object-oriented constructs. Green and Rosemann (2000) have extended the analytical work into the area of integrated process modelling based on the techniques presented in Scheer (2000). More recently, Green *et al.* (2005) and Green *et al.* (In Press) have extended the use of this evaluative base into the area of enterprise systems interoperability using business process modelling languages like ebXML, BPML, WSCI, and BPEL. Recker *et al.* (2006) used representational analysis to identify shortcomings in the Business Process Modeling Notation (BPMN) v1.0. Theoretical findings were tested with nineteen practitioners, resulting in the finding that there exist representational shortcomings in BPMN, for example, in the modelling of business rules, and the usage of the Lane and Pool constructs. Rosemann *et al.* (2006) also examined Petri nets with the use of the BWW representation model. They found that, surprisingly, the notation that consists of a mere seven constructs, provides a relatively high degree of ontological completeness. The study also found that the same flexibility that affords Petri nets a higher ontological completeness, also results in extensive construct overload.

Bunge's ontology underlying the BWW representation model is considered to be the most popular reference ontology used for representational analyses in current research and this situation is clearly reflected in published research. However, as noted before, there are other ontology-based theories that have been proposed as a basis for representational analysis of conceptual modelling in Information Systems. The approaches of Milton and Kazmierczak (2000; 2004) and Guizzardi (2005) are closest to the ideas of Wand and Weber. These upper-level ontologies have been built for similar purposes and seem to be equally expressive (Evermann, 2005) but have not yet achieved the popularity and dissemination of the BWW model. Nevertheless, with increased recognition and popularity of representational analysis in general, it is important to identify an approach for selecting the right ontology as the basis for the analysis.

A META MODEL-BASED APPROACH FOR COMPARISON OF ONTOLOGIES

As a precursor to applying the process of representational analysis, one must first choose the right reference ontology for the task at hand. With a number of upper level ontologies being specified in various languages, this is not an easy task. In order to be able to clearly depict and compare the key elements and constructs of available reference ontologies, meta models of the ontologies should be developed with the use of a common meta language. To demonstrate a meta model-based selection we have translated a portion of both the Bunge-Wand-Weber model and Chisholm's ontology into ER-based meta models (see, for example, Figure 1 and Figure 2 respectively). Through the use of a common meta language such as Entity Relationship models (Chen, 1976), we are able to compare the elements and constructs of each model.

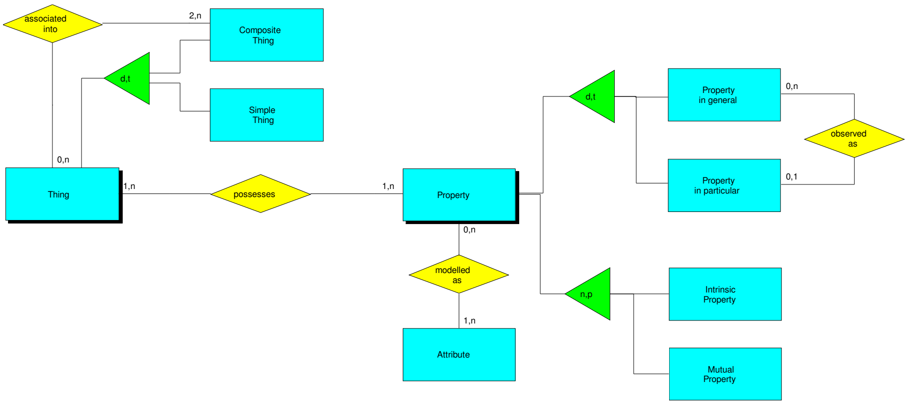

Figure 1: Meta model of BWW representation model constructs

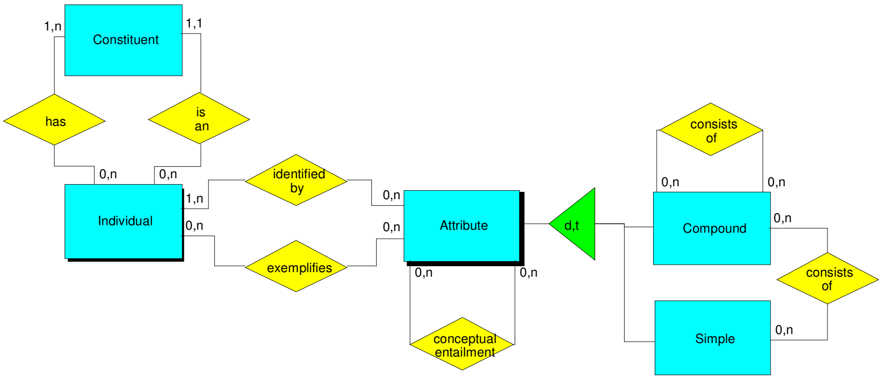

Figure 2: Meta model of Chisholm's ontology

Three different situations can be distinguished when comparing conflict-free meta models for reference ontologies.

a) Between two corresponding elements in two reference ontologies might be a 1-1 relationship. This case describes ontological *equivalence*.

b) It might also be the case that one element in a reference ontology is further specified by two or more elements in the other reference ontology. In that case, the other reference ontology has a *deeper structure*.

c) Finally, it might be the case that one element in one reference ontology does not have any correspondence in the other reference ontology at all. If it can be ensured that all heterogeneous representations including semantic, syntactic and structural diversities have been fully analysed, it can be stated that one reference ontology has a *more comprehensive scope*.

Comparisons can be made by focusing on the difference between: the number and nature of the entities described in each of the models; the number and nature of the relationships between comparable entities; and the cardinality of the comparable entity relationships. Comparing the two models using the three defined situations results in the following analysis:

a) Ontological equivalence

Ontological equivalence can be established between a number of constructs in the BWW representation model and Chisholm ontology. Comparing in the direction from the BWW meta model to the Chisholm meta model, we assert that *Thing* is essentially equivalent to *Individual*; *Property* is equivalent to *Attribute*; and *possess* is equivalent to *exemplifies*. However, when taking cardinality into account a difference between *Property* in the BWW representation model and *Attribute* in the Chisholm ontology can be seen. The BWW representation model stresses that *Properties* can only exist with *Things*. Chisholm's ontology on the other hand asserts that *Attributes* (*Properties* in the BWW model) are enduring and can exist even if not exemplified by any particular *Individual* (Milton and Kazmierczak, 2000).

b) Deeper structure

The BWW representation model takes the concept of *Thing* further by breaking it down by way of generalisation to being either a composite thing or a simple thing. This situation might suggest a deeper structure to the BWW representation model. However, such a structure is implicit in Chisholm's ontology whereby a simple individual is one that has no constituents. Furthermore, *Property* in the BWW representation model is generalised into numerous subtypes, each categorising a property in a particular way. In a slightly different way *Attribute* in the Chisholm ontology is also broken down showing structure. Chisholm structures *Attributes* into compound and simple classifications to enable different levels of expressiveness. This situation may imply that Chisholm's ontology also has a deep structure. Another way in which the Chisholm ontology could be viewed as having a deep structure is the further clarification of the relationship between *Individual* and *Attribute*, one relationship being *identified by* and the other being *exemplifies*. The BWW representation model relates *Thing* and *Properties* via only one relationship - *possesses*. Milton and Kazmierczak (2000) suggest that Chisholm views attributes as being fundamental to his ontology, second only to individuals, which may explain his efforts in further structuring the *Attribute* element and distinguishing further relationships.

c) More comprehensive scope

It is difficult to illustrate comparisons between the scope of the BWW representation model and Chisholm's ontology, considering the limited portion of each meta model chosen and depicted in this paper. Within the restricted boundaries of the meta models represented, however, there is a relationship *conceptual entailment* described in the Chisholm ontology that is not apparent in the BWW representation model. This additional element could be grounds to argue that the Chisholm ontology is more comprehensive in scope. However, when we look at both in their entirety we can see that the BWW representation model appears to describe more constructs than Chisholm's ontology as a whole. Twenty-eight main constructs have been identified in the BWW representation model (Weber, 1997) whereas Milton and Kazmierczak (2000) identify only 12 categories described in Chisholm's ontology and with several other terms defined and mapped back to fundamental categories. Relation and class/set are examples relevant to this paper. This finding suggests that the BWW representation model is in fact more comprehensive in scope. It could also suggest that the BWW representation model is more detailed in its conceptualisation whereas Chisholm's ontology is comparatively terse with respect to the BWW representation model, with Chisholm's descriptive power and comprehensiveness being hidden in concepts such as those concerning attribute, event, and state.

SHORTCOMINGS OF CURRENT REPRESENTATIONAL ANALYSES

Regardless of the choice of the reference ontology for the analytical exercise, we need to be mindful of the potential shortcomings involved in the process of conducting a representational analysis. A representational analysis is in principle the evaluation of a selected modelling technique from the viewpoint of a pre-defined and well-established reference ontology. The current focus of representational analyses is on the bi-directional comparison of the reference ontology constructs with the elements of the analysed language – these comparisons are known as the representation and interpretation mapping respectively (Weber, 1997) (see Figure 3).

Though the process of representational analysis has widely been established, it is not without criticism, refer, for instance, to (Weber, 2003). The shortcomings of this type of analysis can be categorised into the three main phases of the analysis, *i.e.* preparation of the input data, the process of conducting the analysis, and the evaluation and interpretation of the results (Rosemann *et al.*, 2004).

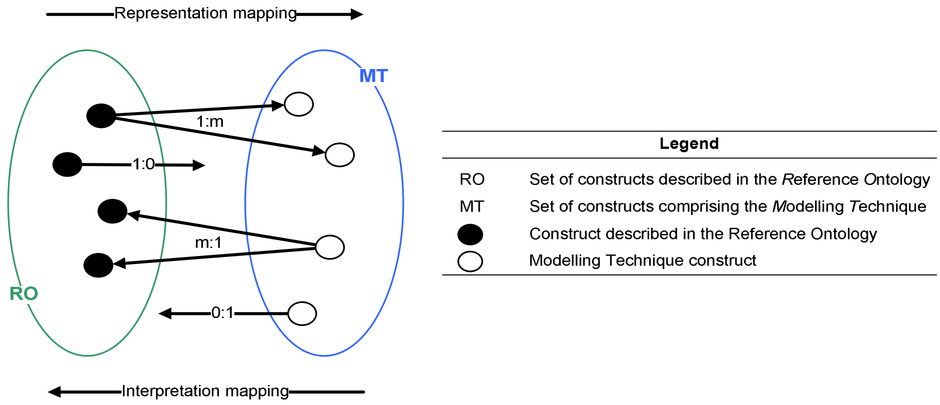

Figure 3: Representation and interpretation mapping. Adapted from (Weber, 1997)

The first two identified shortcomings refer to the quality of the input data.

Lack of Understandability

Most reference ontologies that are currently used for analysis of modelling techniques have been specified in formal languages. While such a formalisation is beneficial for a complete and precise specification of the model, it is not an intuitive specification. A reference ontology that is not clear and intuitive can lead to misinterpretations in the process of conducting a representational analysis as the involved stakeholders have problems with the specifications. Furthermore, it forms a hurdle for the application of the reference ontology as it requires a deep understanding of the formal language in which it is specified. These situations, in effect, can negatively affect the way in which researchers map constructs in the target modelling technique to the constructs in the reference ontology.

Lack of Comparability

The specification of a reference ontology requires a formal syntax that allows the precise specification of the elements and relationships of the reference ontology. Such specifications are required, but not necessarily intuitive. Consequently, textual descriptions of the ontology in 'plain English' often extend the formal specification. However, even if a reference ontology is specified in an intuitive and understandable language, the actual comparison with the language to be analysed remains a problem. Unless the reference ontology and the language are specified in the *same* notation, it will be up to the coder to 'mentally convert' the two specifications into each other, which adds a subjective element to the analysis. Obviously, the coding of two specifications into each other may result in the loss of relevant specification information and thus potentially diminishes the quality of the input data.

The further three shortcomings identified below are related to the process of the representational analysis and refer to what should be analysed, how it should be analysed as well as who should conduct the analysis.

Lack of Completeness

The first decision that has to be made in the process of a representational analysis is the scope and depth of the analysis. Even if most reference ontologies have been discussed for many decades, they still undergo modifications and extensions. It is up to the researcher to clearly specify the selected version of the underlying reference ontology and the scope and level of detail of the analysis. The difficulty in clearly specifying the boundaries of the analysis as well as the limited consideration of relationships between the reference ontology constructs lead to a lack of completeness.

Lack of Guidance

After the scope and the level of detail of the analysis have been specified, it is typically up to the coder to decide on the procedure of the analysis, *i.e.*, in what sequence will the reference ontology constructs and relationships be analysed? Currently, there are few recommendations on where to start the analysis. This lack of procedural clarity underlies most analyses and has two consequences. First, a novice analyst lacks guidance in the process of conducting the representational evaluation. Second, the procedure of the analysis can potentially have an impact on the results of the analysis. Thus, it is possible that two analyses that follow a different process may lead to different outcomes.

Lack of Objectivity

A representational analysis of a language requires not only detailed knowledge of the selected reference ontology and target technique but also a good understanding of the notations in which they are specified. This requirement explains why most analyses are carried out by single researchers as opposed to research teams. Consequently, these analyses are based on the individual interpretations of the involved researcher, which adds significant subjectivity to the results. This concern is conceded also by Weber (1997, p. 94) who contends that “one person’s perception of a mapping between an ontological construct and a grammatical construct might not be the same as another person’s perception”. This problem is further compounded by the fact that, unlike other qualitative research projects, representational analyses typically do not include attempts to further validate results or coding procedures.

Three further shortcomings refer to the outcomes of the analysis, *viz.*, lack of adequate result representation, lack of result classification and lack of relevance.

Lack of Adequate Result Representation

The results of a complete representational analysis, *i.e.*, representation mapping and interpretation mapping, are typically summarised in two tables. These tables list all reference ontology constructs (first table) and all technique constructs (second table) and the corresponding constructs of the other target technique. Such tables can become quite lengthy and are typically not sorted in any particular order. They do not provide any insights into the importance of identified deficiencies and they also do not cluster the findings.

Lack of Result Classification

It is common practice to derive representational deficiencies based on a comparison of the constructs in the reference ontology and the technique. Representational weaknesses are identified when corresponding constructs are missing in the obtained mapping between the reference ontology and the technique or 1-many (or many-1 or even many-many) relationships exist. Such identified deficiencies are the typical starting point for the derivation of propositions and then hypotheses. In general, the representational analysis does not make any statements regarding the relative importance of these findings in comparison with each other. Though this seems to be the established practice, it lacks more detailed insights into the significance of various analytical results.

Lack of Relevance

Finally, the results of a representational analysis should be perceived as relevant by the related stakeholders. Each modelling domain might have different needs regarding the expressive power of modelling techniques, and therefore differing levels of importance for representation of various situations. If a representational analysis leads, for example, to the outcome that Entity Relationship models do not support the description of behaviour, then it is not surprising that the IS community develops a rather critical opinion. It seems that a representational analysis has to consider the purpose of the technique as well as the background of the modeller who is applying this technique. The application of a high-level and generic reference ontology does not consider this individual context and there is a danger that the outcomes can be perceived as trivial.

In the following, we attempt to show how some of the current shortcomings of representational analysis can be mitigated through an improved representational analysis process. We use an example of a representational analysis that has been conducted in the area of enterprise systems interoperability (ESI) and discuss the improved representation analysis process. Furthermore, the ESI domain extends beyond traditional conceptual modelling, which allows us to demonstrate the wide applicability of models of representations and their underlying reference ontologies.

IMPROVED REPRESENTATIONAL ANALYSIS IN THE INTEROPERABILITY DOMAIN

The research area of enterprise systems interoperability approaches the challenge of facilitating internal and cross-organizational integration of enterprise systems by means of precisely defined and agreed standards for communication between the involved systems and business partners. Green *et al.* (2003) proposed that, in order to achieve the goal of *full* enterprise systems interoperability, four fundamental problems must be resolved. First, an agreement must be reached on a general ontology that can be used to describe any type of phenomena that occurs in the real world. Second, an agreement must be achieved on the phenomena that exist within a specific domain and the meaning of those phenomena. Third, an agreement must also be obtained on the mapping of the various phenomena within the domain to the chosen reference ontology. Last, in order to achieve transparent interoperability, a means of replicating the constructivist process that humans use to ascribe meaning to new or existing phenomena of the specific domain must be developed.

In order to further investigate some of these requirements and to show the applicability of representational analysis outside of its usual scope, we have extended the use of representational analysis into the area of enterprise systems interoperability. We have focussed on using the BWW representation model, and an improved representational analysis process, in order to assess the representational capabilities and deficiencies of the most popular enterprise interoperability standards – such as ebXML, BPML, BPEL4WS, and WSCI. We now take the results presented in (Green *et al.*, 2005; In Press), and discuss how representational analysis was improved in order to mitigate some of the earlier identified representational analysis shortcomings. Furthermore, we also discuss the outcomes of these representational analyses of popular ESI standards under some of the assumptions proposed by Green *et al.* (2003).

BWW representation mapping analysis

Being mindful of the shortcomings of representational analyses outlined in the previous section, we extended the current practice of representational analysis and developed an analytical methodology that improved the input, process, and output stages. For the input stage, lack of understanding, comparability, and completeness can be addressed by using a meta-model expressed in a commonly used meta language as the basis for the analytical procedure. Unfortunately, in this situation, none of the target grammars had a meta model expressed in a common meta language. For the process stage, the extended procedure was achieved through the undertaking of individual analyses by at least two members of the research team, followed by consensus as to the final analysis by the entire group of researchers. Each of the candidate standards was dealt with separately using this methodology, in the order of ebXML BPSS (OASIS, 2001), BPML (Arkin, 2002), BPEL4WS (Andrews *et al.*, 2003) and WSCI (Arkin *et al.*, 2002). In the analysis of each of these protocols, four distinct steps were taken to arrive at the final representation modelling analysis.

Step 1: Using the specification of the candidate standard, two researchers separately read the specification and interpreted, selected, and mapped the BWW representation model constructs to candidate technique constructs to create individual first drafts of the analysis.

Step 2: These two researchers met to discuss and defend their interpretations of the representation modelling analysis. This meeting led to an agreed second draft version of the analysis that incorporated elements of both researchers' first draft analyses. In order to assess the degree to which both researchers' first draft analyses agreed, a ratio of the total number of agreed construct mappings to the total number of identified constructs from the specification (by both researchers) expressed as a percentage of mapping agreement was recorded.

Step 3: The second draft version of the analysis for each of the interoperability candidate standards was then used as a basis for defence and discussion in a meeting between the first two researchers and the remaining researchers. Each of the standards was dealt with individually in separate meetings as each of the second draft analyses was finalized. The outcomes of these meetings were the final results for each of these standards.

Step 4: The final analysis for each of the candidate standards became the basis for the second phase of the research, in which a unique set of grammatical constructs was identified.

In terms of the output stage, the issues of lack of adequate result representation, result classification, and relevance will be addressed through future work that empirically tests the results of this extended analytical procedure. Such testing, as that carried out in (Recker *et al.*, 2006), enables the confirmation of the *actual* shortcomings identified through representational analysis that are indeed experienced in practice by modellers of a certain background and with a specific purpose.

Taking the analysis outcomes obtained through the improved process of representational analysis, the technique construct mappings from Green *et al.* (2005; In Press) were analysed in order to arrive at a set of *unique* constructs for the domain of ESI. This process was achieved through the undertaking of a systematic construct comparison that was carried out between technique constructs that had been mapped to the *same* construct in the BWW representation model. This analysis was performed in the same order as that of the initial analyses undertaken in Green *et al.* (2005; In Press), *i.e.,* given a set of constructs that had been found to map to a specific representation model construct, ebXML BPSS constructs were analysed first, followed by the analysis and elimination of equivalent BPML constructs, then followed by the analysis and elimination of equivalent BPEL4WS constructs, and, finally, followed by the analysis and elimination of equivalent WSCI constructs. Adopting this process may result in a situation in which, having had a different starting point, the set of unique constructs found across the four standards may be slightly different as constructs representing the same phenomenon may have different names across the specifications. This situation, however, is not considered to be problematic as the *meaning* of the constructs is the same, regardless of the construct name chosen by the specification's authors.

Phenomena within the enterprise systems interoperability domain

Green *et al.* (2003) argue that one of the requirements of achieving full interoperability is the *a priori* agreement on the set of phenomena that exist within the domain being modelled. By utilising the BWW representation model and the improved process of representational analysis, we analysed the leading standards in the ESI domain in order to identify the set of 'common' phenomena needed to represent the requirements of enterprise system interoperability.

The analysis of these standards has shown that there exist some representation model constructs with no representation in any of the four standards (Green *et al.*, In Press). The analysis has also shown that, while there is an overlap between these standards, each standard adds additional constructs for the purpose of facilitating interoperability. From this analysis we can deduce the set of unique constructs required for the enterprise systems interoperability domain, as represented by the four leading standards *viz.* ebXML, BPEL4WS, BPML, and WSCI. Table 1 lists the obtained set of constructs, while differentiating them by the standard from which they derive.

ebXML	BPEL4WS	BPML	WSCI
Business Partner Role	Correlation Set	Property	Set of properties
Authorized Role	Partner	Property Instance	One-Way Action
Attribute Definitions	Set of variables	Names of Properties	Request-Response
Business Document	Reply	Signal	Action Notification
Document Envelope	Create Instance (on Activity)	Message	Action
Attachment	Wait	Event (Process Defn.)	Solicit-Response
Start	Event Handler	Instant (Schedule Defn.)	Action Instantiation (Process)
Success	Receive	Action	Delay
Failure	Throw	Assign	On Timeout
Fork	Terminate	Fault	On Fault
Join	Alarm Event (onAlarm)	Raise	Model
Wellformedness Rules	Message Event (onMessage)	Compensate	
RequestingBusinessActivity	Pick	Compensation Process	
RespondingBusinessActivity	Role	Exception Process	
Business Transaction	Service Link	Process	
<preCondition,postCondition> on Business Transaction & Binary Collaboration	Business Process Instance	Fault Handler	
Transition	Partners	Schedule	
Transition obeying Wellformedness rules		Transaction	
Choreography		While	
BusinessTransactionActivity		Until	
CollaborationActivity		Switch	
Binary Collaboration		Condition	
Multi-Party Collaboration			
Binary Collaboration			

Table 1: Set of unique constructs across the four ESI standards

While this derived set of constructs can serve as the description of the currently assumed modelling requirements of ESI, agreement on this set alone is not enough to facilitate a greater extent of interoperability. In order to increase such capability, there must also be an agreement on the mapping of these phenomena, or technique constructs, to the chosen reference ontology. If such an agreement does not exist, interoperability will be hampered by assumptions of ontological equivalence where none exists. Essentially, even if two machines use the same general reference ontology to represent domain phenomena, they must also use the same mapping between domain phenomena and the reference ontology if interoperability is not to be limited (Green *et al.*, 2003). Suggested mappings using the BWW representation model as a reference ontology and detailed explanations of the mappings for each of the constructs of Table 1 are presented by Green *et al.* (2005) and Green *et al.* (In Press).

Even if the three required steps are achieved, there is still a need for a process that, where confusion has occurred, allows meaning to be negotiated and assigned to constructs by the interacting parties. Green *et al.* (2003) propose that the current lack of such process significantly limits full interoperability. Indeed, Green *et al.* (In Press) found that many constructs across the four standards exhibit excess, therefore, potentially being likely causes of such confusion among users. Hence, when a company uses one or more of these 'excess' constructs in an implementation of interoperability for its information system, the implementer(s) may have a different understanding of some of the constructs from those used by implementer(s) at another company. A partial solution to this problem may lie in AI systems. Although limited in its use, an AI-based system sensitive to the *domain-focused* ontology of systems interoperability may be able to be used to partially negotiate and ascribe consensual meaning for those *excess* constructs. In this way, the three steps can provide a basis on which to mitigate the current problem for systems interoperability of implementing the equivalent of a human constructivist process to ascribe meaning.

SUMMARY

This paper has argued that representational analysis is a popular and useful approach to the evaluation of not just conceptual modelling techniques but any communicative technique in which there exists semantic meaning underlying the technique constructs. The representational analysis must be based on a general reference ontology, however, there are several candidates for such an ontology. How do you choose the appropriate reference ontology for the analytical task at hand? This paper contributes to the theory of representational analysis by explaining how a meta-model approach can be used to represent and compare two or more different reference ontologies. In this way, an appropriate reference ontology can be selected for an analytical process. In particular, we argue that ontological equivalence, deep structure, and comprehensiveness of the scope of the candidate meta-models can be used to evaluate and select the required reference ontology. Having selected the reference ontology for the analytical task, there exist shortcomings in the current analytical procedure of which the researcher must be aware. In this paper, we identify these shortcomings and provide guidance, through the use of an example, on how to mitigate some of them. Furthermore, we demonstrate the usefulness of a reference ontology applied in an improved manner to four candidate standards for ESI. The resultant set of 'common' constructs, at this time, appears to constitute the domain of concepts required for achieving enterprise systems interoperability.

Our further work in this area involves testing the predictions from the analyses performed with implementers of organizational solutions for ESI in industry.

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