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Ontological Foundations of Representational Information Systems

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An Australian Perspective

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Abstract. A research program around the idea that information systems represent real-world systems was started almost twenty years ago. The program started by Wand and Weber is still going strong with a significant amount of research inspired by them and is one of the few instances incremental foundational research in Information Systems. Much of this research is being undertaken in Australia, and its influence has spread far and wide. Wand and Weber have used ontology, a discipline with roots in two thousand years of philosophy, to drive empirical work into how well information systems represent reality. In this paper the inspiration and progress of the program of research followed over the past two decades is described. The research program has recently progressed from its roots examining information systems development to examine enterprise systems and other package solutions. Further, it is beginning now to more fully use the depth of ontological theory available. However, there are challenges in how Bunge's ontology has been used and opportunities for using complementary ontologies and for different conceptualisations of information systems.

Keywords: ontology, representation, information systems design, conceptual modeling.

1 Introduction

For over two thousand years, ontology has concerned understanding the most general categories needed in constructing a description of reality. Each ontology defines the most general categories, and it tells us how these categories are related. It also describes reality without specifying the particulars of any category. It must further be able to be used to describe reality at any point in time (either now, or in the future, or in the past). This account is in keeping with the definitions of ontology found in the standard philosophical literature, for example:

- “The study of being in so far as this is shared in common by all entities, both material and immaterial. [Ontology] deals with the most general properties of beings in all their different varieties” (Kim and Sosa 1995).
- “Ontology, understood as a branch of metaphysics, is the science of being in general, embracing such issues as the nature of existence and the categorial structure of reality. … Different systems of ontology propose alternative categorial schemes. A categorial scheme typically exhibits a hierarchical structure, with ‘being’ or ‘entity’ as the topmost category, embracing everything that exists” (Honderich 1995).

Philosophers also construct ontologies for specific domains such as physics, biology, medicine, or geography, with categories that are designed to be sufficient to support the representation of all the entities in the corresponding domain, for example—in the biological case by means of categories such as: gene, amino acid, protein, cell. Such ontologies are driven by philosophical theories. These domain-specific ontologies can be categorized as being heavily theory focused.

The disciplines of artificial intelligence (AI) and computer science (Vet and Mars 1998; Vickery 1997), in contrast, often use ontologies in highly pragmatically motivated ways:

- “in its most prevalent use in AI, an ontology refers to an engineering artifact, constituted by a specific vocabulary used to describe a certain reality, plus a set of explicit assumptions regarding the intended meaning of the vocabulary words” (Guarino 1998).

Reflecting these two ideas, ontology in informatics (information systems, software engineering and computer science) comes in at least two flavours. First, highly general ontologies—sometimes called top-level ontologies, often based on ideas taken over from philosophy and used to analyse information systems and their design tools and methods (Milton and Kazmierczak 2004; Niles and Pease 2001; Smith 1998; Wand and Weber 2002; Wand and Weber 1990; Wand and Weber 1989). Second, domain ontologies restricted to specific fields such as medicine, accounting, or geography. Top-level ontologies are used to provide a theoretical underpinning for representation and modeling in information systems (Wand and Weber 2006) in ways designed to bring benefits in the form of more reliable applications, better quality data-creation, and also help in error-detection. Domain ontologies are aimed at facilitating automated data sharing between complex information systems in specific fields and also at supporting the automatic construction and population of ontologies developed in these fields.

This paper focuses on ontologies of the first highly general, philosophical kind: those concerned with the most general categories referred to when constructing a description of reality. Further, it concentrates on how the discipline of information systems uses ontologies of this character in understanding representational information systems and more broadly the role of representation in analyzing, designing, or customizing information systems.

Two top-level ontological theories have been applied in analytical studies of modeling tools and techniques in informatics. Both of these theories come from the philosophical tradition of realism, one from naturalism (Bunge 1977; Bunge 1979), and the other from Aristotelian common-sense realism (Chisholm 1996). Both have been found to be supported by most modeling tools (Milton and Kazmierczak 2004; Wand and Weber 2002).

A large percentage of research into top-level philosophical ontology, inspired by Wand and Weber (1993) has been undertaken in Australia. For example, my own research using Chisholm's ontology, the first comprehensive study of modeling languages using that ontology (2000), was thus inspired. Ontological research in Australia has been raised another notch in recent years, and the majority of Wand and Weber inspired ontological research is being undertaken in two Australian cities. Firstly, in Brisbane, *Green* and *Rosemann* with *Vessey* and *Weber* are examining enterprise systems using ontology. Secondly, in Melbourne, *Weber* and *Shanks* lead teams continuing examinations of conceptual modeling tools and practice. Further, there has been debate ignited by *Wyssusek* from Queensland University of Technology in Brisbane on the use of Bunge's ontologically rich Volume II and Bunge's philosophy more broadly (Rosemann and Wyssusek 2005). More recently, Wyssusek has voiced more fundamental doubts over the overall program of using ontology in information systems (Wyssusek 2006). Indeed the debate has presented a good opportunity to take up Kalle Lyytinen's call that the discipline "scrutinize more carefully both the theoretical assumptions and practical implications of the modeling program by Wand and Weber" (Lyytinen 2006).

This paper examines the basis of a theory of representation in information systems and the relationship with a conceptualization of what constitutes an information system emerging from Bunge's ontology. The paper firstly considers the whole idea of an information system representing real-world systems. It then discusses the ontology used to develop information systems of that type before examining two streams of research using the conceptualization into conceptual modeling and enterprise systems. The conclusion is that other ontologies beyond Bunge's may be useful in informatics for a range of representational purposes. Further, that other conceptualizations of what is an information system may be desirable. Nevertheless, there is merit in the broad program for a theory of representation in information systems.

2 Information Systems as 'Representing Real-world Systems'

Wand and Weber (1989) first proposed the representational model of an information system in the mid to late 1980s. Heavily influenced by their own practical, research, and teaching background (Wand and Weber 2006) and by systems theory in the several decades prior to this, they proposed a view of an information system as a representation of some real-world system: "My argument, that ontological theories provide the foundation for conceptual modeling research, practice, and pedagogy, rests on a single, fundamental proposition—namely, that the essence of an information system is that it is a representation of some other real-world system" (Wand and Weber 2002).

Wand and Weber see an information system as having three major levels of structure. Firstly, a user of an information system is aware of *surface structure* such as interfaces, reports and other elements. Secondly, an information system has *deep structure* that handle the representational aspects through databases and applications programs that are instrumental in presenting information from the representational models to users. Finally, the system has a *physical structure* that is supported in information technology through compiled low-level code, permanent and volatile memory and the electronic devices.

The focus of Wand and Weber's ontological research is deep structure of an information system. Indeed, having established the idea of what constitutes an information system, Wand and Weber proceeded to describe how such a deep structure is designed.

2.1 Designing and Building an Information System

The first step in designing the deep structure of an information system is establishing an agreed *domain of discourse*. This involves various professionals including systems analysts and domain experts as well as affected users. For example, should an organization be interested in building an order-entry-sales system the domain of discourse is that part of the world affected by the real-world order-entry-sales system. The people consulted are those who use the system or have an interest in the system's use and performance.

The process, shown in Figure 1, begins with an analyst examining a system in the domain of discourse to be represented in an information system. The analyst uses various types of scripts to construct representations of the domain of discourse. These scripts can then be used in constructing an information system to represent systems from the domain of discourse.

In this way, an analyst proceeds by interviewing people who use, analyse, and understand the real-world system. In interviews the analyst seeks descriptions about how the real-world system works. The analyst then represents the real-world system, as each interviewee sees it, in a script. The scripts, at this stage in the process, are non-technical in form. Script 1 and script 2, from Figure 1, are examples of this.

This proceeds until a range of representations of the real-world system are scripted, one for each key group of people or stakeholders who have experience or know the real-world system. Total agreement is unlikely at this point, so there is a process of reconciling the scripts to create a consolidated representation of the real-world system, with transformations of scripts mirroring the reconciliation.

The scripts change through the analysis process from heavily user-oriented, close to the domain of discourse, to heavily machine-oriented. The form of scripts thus changes. Each form of representation has a grammar that structures representations. The script executed in the information system, called *script n* in Figure 2, is likely to be in compiled code and executing modules or systems such as database management systems. Scripts close to the domain of discourse are likely to be transcripts or notes from informal semi-structured and structured interviews or focus groups, or semi-formal scripts such as use-cases and other user-centred representations. Between these two types of script more formal scripts are used. Entity-Relationship (ER) diagrams, Unified Modeling Language (UML) formal models, or process diagrams formalize ideas of the system. These are transformed into database descriptions and specifications for modules to be coded.

Enterprise systems are often used to standardise information systems in organizations allowing easy exchange of information between parts of the

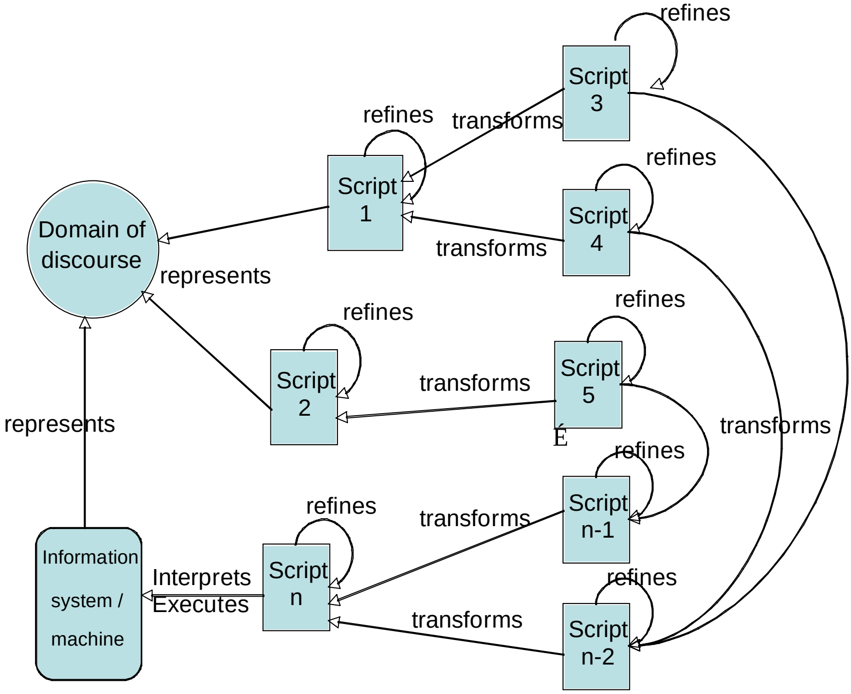

Figure 1. The process of script transformation leading to an implemented system (Wand and Weber 2002)

business and standardization of systems across business units. In this context, Wand and Weber would maintain that their view of what is an information system still holds. The main difference is that there are scripts reflecting 'world best practice' in enterprise systems that replace those previously analysed, designed and built from scratch. Specifically, scripts are still executed in information systems much the same way as before and an information system still represents real-world systems. Different mechanisms are established to gather business requirements that lead to the selection, and customization of the enterprise system, and to changes in organizational processes during implementation.

Having established that information systems represent real-world systems, Wand and Weber have established two measures of system quality: Accuracy, where "the meaning manifested in each component of the deep structure of an information system must be the same as the meaning manifested in each component of the user's model of the real-world system that the information system is supposed to represent", and completeness, where "the meaning manifested in the user's model of the real-world system must be fully articulated in the deep structure of the information system that is supposed to represent the users' model of the real-world system."

There are many complex influences in implementing an information system because of the long path from a specific business need to having an implemented information system. Firstly, each script is constructed according to the modeling grammar that governs the rules by which it is created. Secondly, a modeling method, applied by a business analyst, indicates how the modeling grammar is used to build scripts. Further, the modeling method is applied in a modeling context where organizational needs, individual difference, both the modeler and the people from the organization, and social influences affect the application of the modeling method.

An organisation's processes and existing data stores inform the assessment of potential enterprise systems. Following this, real-world systems are often changed to match those assumed by an enterprise system. This is called a 'vanilla' implementation. Alternatively, where the path of customising an enterprise system for an organization, there is need to ensure that the enterprise system is customized to match the processes of the organization.

Vendors of enterprise systems claim their process models match best practice in each family of processes. Further, from Weber's concept of an information system, databases holding data in enterprise systems should be able to represent parts of the 'real-world system best practice'. Ideas of goodness of representation are still central.

Whether building an information system from scratch or utilizing an enterprise system from a vendor, according to Wand and Weber's conceptualization, the quality of the information system hangs partly on how well it represents the real-world system it is mirroring. Thus a key focus is ensuring better quality information systems using ontology.

2.2 Improving the Quality of Representational Information Systems: How Ontology Helps

Wand and Weber argued that the representational quality of information systems is fundamental to the quality of an information system (Weber 1997). Based upon this, they outlined a research program researching this proposition. More precisely they asked "Given a user's or group's conception of the real-world, under what conditions would an information system provide a good or a poor representation of this conception?" (Weber 1997)

Two fundamental research questions logically follow:

1. What are the set of generic constructs that people employ to structure their conceptions of the world?
2. Do the tools used to build information systems provide a means to represent these constructs?

On the face of it, the questions seem to have more to do with conceptions people have rather than representations of the world. However, Wand and Weber are fundamentally interested in understanding an information system through the conceptualization "that [an information system] was intended to be a representation of the real-world as perceived by someone or some group of stakeholders" (Weber 1997). Thus both questions require investigation of the generic constructs that can be used to represent the real-world, and how well the tools used to build information systems support the constructs for representing the real-world. For this, they used the mature field of ontology.

In constructing an information system as envisaged, it is important to get the representational terms correct. These terms are used in the languages of scripts. Further, the fidelity with which the information system represents a real-world system is best arbitrated by ontology. Ontology is useful because it defines the most general categories for constructing descriptions of reality, and how these categories are related. It thus describes reality without specifying the particulars of any category.

The categories in an ontology are generic constructs by which models of the world are built. Therefore, of its very general nature, each ontology outlines the general constructs needed in describing reality. Further, tools used to build models of reality can be methodically assessed against ontology to assess the quality of the tool against the way that ontology 'cuts up the world' (Milton 2004).

Importantly, an ontology not only has constructs that are used to help segment reality, it also has philosophical commitments that underlie the constructs. An ontology, implicitly or explicitly, brings with it a philosophy, and a position towards reality.

3 Bunge's Ontology

Having established ontology as a body of theory from which to extract a set of generic constructs in representing reality, what remains is determining which of the many ontologies should be selected. Wand and Weber selected the ontology of Bunge to act as the representational theory from which to determine the generic constructs one can use to build representations of the world

(Weber 1997), or help implement enterprise systems that perform a similar job.

3.1 Bunge's Ontology: Overview

Bunge's philosophy states the world is a world of systems (Bunge 1979). According to Bunge's ontology, all things in the world, except for the very basic elements such as quarks, are systems of some sort. The world is built on physical, chemical, biochemical, and biological systems. Upon those systems rely psychological, sociological, and technical systems. Each system 'higher' in the typology relies on the systems below it: thus, without physical, chemical, biochemical, biological, psychological, and sociological systems one cannot have a fully functioning human society. Bunge argues that human beings rely both on the physical world and that of fundamental biochemical and biological processes and so on. Figure 2 shows the various levels.

The role of science is foundational in describing the various systems theoretically prior to describing the specifics of 'here and now' and of how the system changes over time. In this tenor, the various disciplines of science are the only way to tell us the nature and constituents of the systems and sub-systems and the other categories. These will tell us what sorts of things exist and how change is explained through the laws and lawful states that any system obeys or passes through. Eventually, one builds up an understanding of the world in its complexity. One could build a model of it and instantiate the current situation at a level of abstraction and with some focus or purpose.

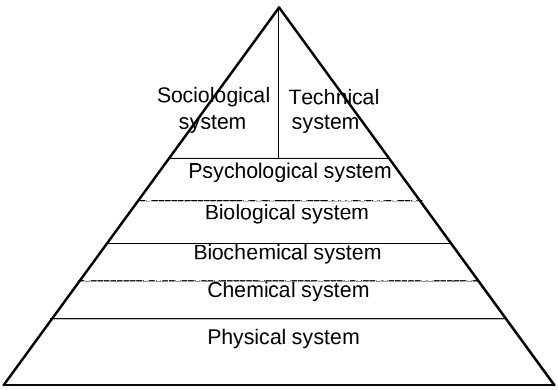

Figure 2. The typology of systems (Bunge 1979)

3.2 Bunge's Categories

Bunge's ontology is one based on systems and things. Bunge (1979) found that science can explain the various types of systems shown in Figure 2. He demonstrated how the detail could be fleshed out using scientific domains such as sociology, physics, and biochemistry. Further, sociological systems such as those in the fields of politics, and economics can give further details of systems at the sociological levels. Some systems, such as the monetary system, are created and used by people. Further, physical artifacts are created and used as tools in such sociological systems.

Many ontologists provide a taxonomy or categorical scheme with the ontological theory. An ontology's categories and terms are critical to undertake analysis of representation (Milton and Kazmierczak 2004). Shown in Figure 3, it depicts the ways in which key ontic terms are related. The terms are ontic in that they relate to what exist.

'Thing' is the fundamental building block. From this, Bunge moves to analyse each thing into constituent parts. Very few things are basic, although subatomic particles are the most likely candidates in present understanding. Any 'thing' that is not basic is also a system at some lower level of granularity.

Most things are systems at a different level of generalisation. Each system may be open or closed. There are very few closed systems. The universe may be an example of a closed system. Open systems are either conceptual, such as mathematical systems, or are concrete. Each concrete system is either a prop-

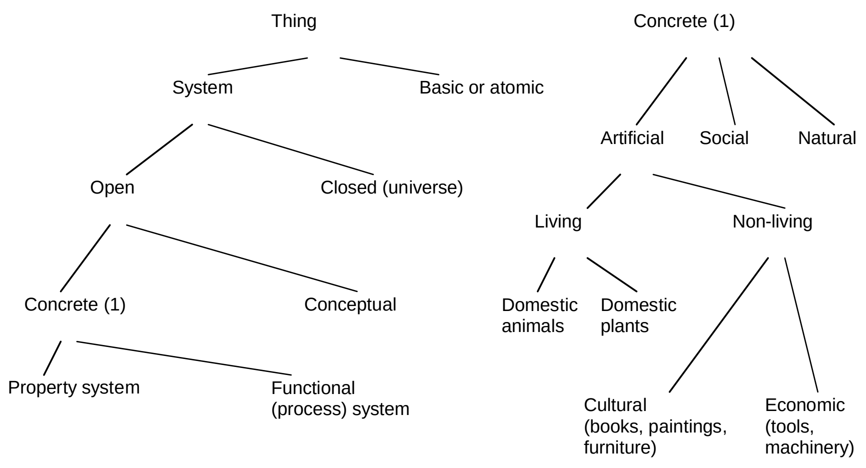

Figure 3. The categories in Bunge's ontology (Bunge 1977)

erty system that has spatial-temporal existence, or a functional system (process).

A ‘Concrete system’ is social, natural, or artificial. An artificial system may be living or non-living. For example, domestic animals and plants are seen as artificial, due to human intervention through generations of animal husbandry and plant genetic manipulation through selection. A category of non-living artificial systems is economic and cultural systems. Technical parts of information systems may be seen as members of the category of non-living economic artificial concrete systems.

The structure of his taxonomy reveals much about the nuances in Bunge’s ontological scheme and his desire to complete a well-argued theory driven by understanding of the complex world through science. Further, he devised an intricate, complex, systemic understanding based on the materialist realist perspective he believes (Milton and Kazmierczak 2006; Wyssusek 2006)

Like many ontologies, the constructs in Bunge’s ontology addresses two distinct areas: statics, and change through property and functional systems respectively. The statics and dynamics of systems help to describe the world at any specific moment and how change affects the description.

The constructs define, at a given level of granularity, basic building blocks: things, properties of things, including part-whole relationships, and related constructs to frame the statics of the world. Additionally, one can discuss how the world changes over time as governed by laws of various types (not all are causal laws), and be able to follow change through histories of things.

The premise of Bunge’s ontology is that by studying how all types of systems behave brings a fuller understanding of, and an ability to predict how, complex socio-technical systems behave. An information system may be seen as sociological system that uses, often complex, technical systems. The emergent properties and behaviour of information systems result from the interaction of a sociological system and complex technology (Lee 2001).

3.3 Bunge’s Philosophy: Scientific Realism

For Bunge, there is a distinction between the world and our model of it. One cannot know the world directly and it is only through models encapsulating theories of the world can the world be known (Bunge 1977). Further, our knowledge is likely to be imperfect in that qualities that are discerned by measurement only *relate* to fundamental properties that things possess to a greater or lesser extent but never perfectly. Only that for which a model can be built can be known in this strict scientific sense. Thus, there is a strong sense that the model is apart from that bit of the world under study and is used to mediate an understanding. This style of ontology, because of its privileging of any science and its desire to understand the natural world, is called naturalistic or scientific (Kim and Sosa 1995) because the objective is to analyse the nature and constitution of the world using the best of available science and to model it. This view is put very strongly by Bunge: "it is only through science can we know the world" (Bunge 1977).

There is no room for any other interpretation of the world and our relationships to it as people. Bunge (1977) is extremely certain that any other type of ontology is impossible. Only through a deep understanding of science through its disciplines and by using a model of the world can you know about the world.

Having adopted Bunge's ontology as a reference theory, Weber with Wand adapted the first volume of Bunge's ontology to information systems (Wand and Weber 1989). It is a simplification of Bunge's ontology and has since become known as the 'BWW' or 'Bunge-Wand-Weber' ontology.

4 Using Ontology to Assess the Representational Quality of Information Systems

A research agenda, inspired by Wand and Weber, has been pursed for the best part of two decades. The most productive has been that examining conceptual modeling where building systems is the focus. A second recent phenomenon is using ontology in studying projects implementing enterprise systems where an organization buys a customizable large system to support enterprise-wide processes—now a more common approach.

4.1 Conceptual Modeling Research: Building Systems

The agenda for conceptual modeling research broadly fits into two areas—into the grammars or tools such as the ER modeling framework, and into the context, the practice, and the scripts produced through the practice of conceptual modeling in information systems.

Conceptual Modeling Grammars

The earliest and the largest body of work in this research agenda concerns conceptual modeling grammars. At the time there was a proliferation of modeling grammars (Hull and King 1987; Peckham and Maryanski 1988). This proliferation coined the acronym YAMA for 'yet another modeling approach'. Ontology was suggested as a gauge to the usefulness of a particular modeling approach to 'describe the structure and behaviour of the world in general' (Wand and Weber 2002).

In Wand and Weber's conception, the deep structure of an information system is designed partly by applying grammars that are used to represent aspects of a real-world system. The representational quality of design grammars is at the core of the representational power of information systems as conceived by Wand and Weber. By 1993 they presented a more formal understanding as to how well different data modeling tools and associated grammars represent the types of things that exist (Wand and Weber 1993). Figure 4 shows this mapping.

Using this, the representational quality of a modeling grammar can be understood. The ontology is considered to provide a measure of 'goodness' and there are two mappings that help evaluate modeling grammars. Firstly, the 'representation mapping' shows how well a modeling grammar represents the sorts of things that exist. Secondly, the 'interpretation mapping' tells us how easily one can understand the grammar based on how well it supports ontological constructs. The less noisy or overloaded these mappings, the better the modeling grammar is at representing the world as conceived through the ontology. There is an understanding that any ontology may be used in the comparison, but also there is an implied search for the 'best' with which to undertake comparisons. Others disagree with the search for an absolute ontology (Milton and Kazmierczak 2004 & 2006; Wyssusek 2006).

Evaluating the 'representational mapping' results in four types of shortcomings encompassing the possible relationships between the modeling grammar's constructs and those of the ontology. These are presented in Table 1, below. Ontological completeness is when none of these four categories of shortcoming apply.

Often more than one modeling framework is applied in modeling aspects of a system. Thus, examining each tool for ontological completeness is only part of the story. To complete the picture, the ideas of minimum ontological overlap (MOO) and maximum ontological coverage (MOC) help to guide people when selecting modeling tools in a methodology. Essentially, MOO is

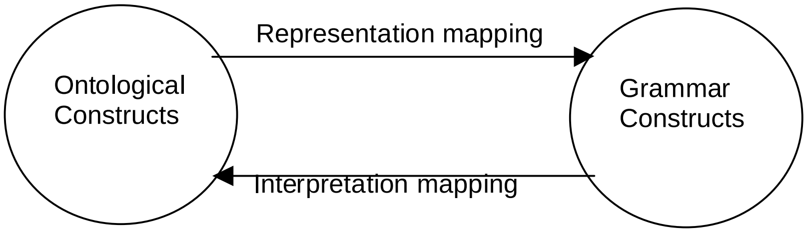

Figure 4. Measuring a modeling grammar against an ontology (Wand 1996; Wand and Weber 1993)

required between tools used, and all tools applied in modeling for a specific information systems implementation taken together should satisfy MOC. For example, by using Entity-Relationship (ER) modeling and process modeling using Data Flow Diagrams (DFDs), one may reach maximum ontological coverage and minimize ontological overlap over both modeling tools taken together. This should be true for most methodologies, but the question is important and by more deeply understanding the role of each modeling grammar helps to strengthen each methodology.

Category	*Definition*
Construct Overload	Several ontological constructs map to one grammatical construct
Construct redundancy	Several grammatical constructs map to one ontological construct
Construct excess	A grammatical construct has no corresponding ontological construct
Construct deficit	An ontological construct has no correlating grammatical construct

Table 1: Shortcomings evident from an ontological evaluation

The second mapping in the method evaluating grammars, called the 'interpretation mapping', establishes how clearly a modeling tool can be used to present real-world phenomena to someone interpreting a model built using the grammar. In these cases even though all constructs from the ontology are represented in the grammar, there are constructs in the modeling grammar that do not have an ontological correlate or where two ontological correlates are required to fully represent the grammar's construct in the ontology. However, it has influenced research into how well people understand and use models.

Bunge's ontology has been used to analyse many modeling grammars including ER, DFDs, and various UML model types. The findings, although highlighting areas of ontological weakness, broadly showed that Bunge's ontological basics were supported by the tools.

Applying Bunge's ontology suggested a number of possible avenues of further research. Pivoting on the assumption that Bunge's ontology is an arbitor of 'goodness', researchers began to use the ontology to set ontologically sound and unsound aspects of modeling. This encompassed a range of topics including whether or not to use optional attributes, how to represent relationships between entities, what is the quality of a data model, and what is a good decomposition of a system's data model into parts. These issues clearly move beyond just assessing the modeling grammar in tools such as the ER modeling framework to the methods applied, the context in which they are applied, and the scripts produced. It begins to examine far more directly epistemological aspects of modeling methods in context.

Modeling Methods, Context, and Scripts

Evaluating grammars using ontology is only part of the story because the grammars are applied using methods, are applied in a context, and produce scripts of varying quality. The explicit reach of ontology diminishes significantly when examining these areas. For example, philosophical ontology is really only directly suitable for meta-theoretic evaluations at the grammar level because they concern general categories into which one can cut the world (Milton and Kazmierczak 2004 & 2006).

A specific ontology defines the most general categories of 'what exists'. It describes the nature of the categories and it tells us how the categories relate. It specifies what is needed to describe reality without specifying the instances of any category. Precisely because ontology does not aim to specify each instance of a category it plays the role of a meta-theory for languages that do aim to describe instances. For example, the existence of this or that type of car and its various part-whole relationships are not general enough for ontological consideration of the type already outlined. Neither can an ontology comment on how individuals use and create models, known as individual contextual factors, the sorts of tasks one undertakes with models, called task contextual factors, and the specific values, beliefs, and perspective of the people comprising the organization for which the task of designing a new car is being performed, expressed as social agenda factors. Still further, it is unclear how much the quality of a model of the car can be arbitrated or assessed by a specific ontology.

Thus, one would expect that the topic of modeling methods, contexts, and scripts produced would not involve ontology. Applying modeling formalisms or grammars in modeling activities in specific contexts producing specific scripts is an epistemological issue. However, one cannot completely divorce oneself from ontological concerns. This is because the very stuff of conceptual modeling when building systems can be influenced by an ontological position or be improved by appealing to general ontological methods and theories (Smith 2004; Milton 2004).

This is illustrated in many of the studies cited in (Wand and Weber 2002), including (Opdahl et al. 2001; Parsons and Wand 1995; Paulson and Wand 1992; Wand and Woo 1993; Wand et al. 1993) investigating modeling methods, that are explicitly influenced by Bunge's ontology (things, properties/attributes, couplings, mututal properties, decompositions and level structures) or by more general ontological principles (meronymic or part-whole relationships, classes, events, processes). Even those examining work-flow and class structures implicitly assume an ontological position that goes beyond formal ontology. Indeed, many of the studies into contextual issues have been quite directly influenced by either general ontological theories (such as mereology) or by the ideas coming directly from Bunge's ontology itself. Mereology concerns the study of part-whole relationships, and is well represented in Bunge's ontology and is a significant part of standard modern ontological practice and theory.

Ontologically inspired research also concerns the interpretability and understandability of scripts. The sub-text being that producing the best representational script is an important goal in improving information systems and thus in building 'good' representational information systems. It is assumed that ontologically clear scripts will be more understandable than unclear scripts. Based on this premise a large number of experiments have been undertaken over the best part of the last decade. Part-whole relationships (Shanks et al. 2003; Shanks et al. 2004), general relationships, and optional properties (Bodart et al. 2001) have been popular avenues for research.

Changing the ontology used may change the direction of research. For example, the rejection of optional properties as being unsound ontological is a direct result of Bunge being disinterested in type and token differences and the central role played by classifying things. Other ontologies, for example Chisholm (1996), do not have this restriction because of the recognition of type and token separation and the role classes have. Weber and Wand are both interested in more ontologies being used in research (Wand and Weber 2006). The implicit ties to Bunge's ontology, as represented by the optional properties question would need to be addressed for this to become a reality.

One should be cautious in using ontology with specific models. An ontology speaks of the most general categories into which things fit and the terms needed to support the description generally. Thus any ontology is at its strongest when it is used to understand, explain, and assess the theoretical constructs proposed in a specific modeling language. A specific ontology is less useful when considering a specific model of a company like Nokia, or a specific type of Mercedes-Benz car. It is important only to include in the analysis those things considered to be general ontological principles and modeling tools capable of being used in such specific cases.

Thus far only information systems analysed, designed, and built have been considered through the modeling process, tools, outputs, and techniques. Many organizations are turning to enterprise-wide information systems called enterprise systems.

4.2 Enterprise Systems and Ontological Research

Information systems are now rarely built and package systems are often installed that work across organizational functional boundaries and allow sharing of data and processes. One of the biggest class of package software is called enterprise systems. Enterprise systems often handle systems that readily fit the representational style already detailed in this paper. Thus, a major program of ontology based research into enterprise systems.

There are two major parts to research into enterprise systems. Firstly, enterprise systems have been the catalyst for advancement in organizational process modeling tools. Given the wealth of research previously, it was logical that an ontological analysis of the representational capacity of process and integrated modeling tools would follow. Secondly, organizations desire a good fit between the information needs of business processes and an enterprise system. Indeed one could argue that this alignment is critical to successfully implementing enterprise systems.

Process Modeling

One vendor of enterprise systems supports a toolset called the Architecture of Integrated Information Systems (ARIS) toolset (Scheer 1998) that supports process modeling. However, ARIS is an integrated approach between process, data, and organizational function. This contrasts with traditional process views where data and function are not integrated adequately.

An important part of representational research into enterprise systems thus began as an ontological evaluation of the process modeling tool, Event Process Chains (EPCs), in the integrated process approach of ARIS (Green &

Rosemann 2000). The findings were that the process view is not sufficient to encapsulate all the ontological constructs from the ontology and found that the ontology needs to be extended to accommodate "business objectives, strategies, goals, or knowledge" (Green and Rosemann 2000).

Green and Rosemann hypothesized that the result was such because either, the ontology is over-specified, or that EPCs will fail in real contexts. Five propositions emerged concerning ontological incompleteness in EPCs. The program shifted to testing these hypotheses with groups familiar with EPCs. Inconclusive results (Green and Rosemann 2002) led to six clearer propositions that the modelers would:

1. Be confused between which symbols to use for some real-world constructs, as there were cases where more than one symbol carried the same ontological meaning.
2. Have difficulty representing all the necessary real-world constructs directly, as there were cases where no symbol for some real-world constructs existed.
3. Have difficulty representing the explicit properties of things.
4. Have difficulty representing important business rules.
5. Have difficulty representing the scope and boundaries of the entire system.
6. Have difficulty representing the structure and decomposition of the system (Davies et al. 2004).

Four hundred modelers were surveyed and a further twenty-one interviewed from eight organizations in the public and private sectors. The results were similarly inconclusive (Davies et al. 2004). The outcome is that new propositions will be formulated and tested. However, it is also possible that the research methods applied are failing to adequately study the use of tools in real contexts.

The EPC tool as part of ARIS is not the only approach to process modeling. Thus, a further study into process modeling approaches has been undertaken examining a range of process models Petri nets through to BPMN (business process modeling notation). It found that BPMN provides a reasonably comprehensive coverage of relevant ontological concepts. However, the results are preliminary due to the sample being small. More research is expected into integrated process modeling.

Organisational Needs in Enterprise Systems

Selecting an enterprise system and deciding whether and how to customize it are for implementing enterprise systems. Globally, many billions $US are invested annually in enterprise systems and associated services. Ontological distance is a measure recently proposed (Rosemann et al. 2004) that more adequately assesses the suitability of an enterprise system, for a specific organization.

Ontological distance is designed to measure how well the capabilities of the enterprise system match the needs of an organization. The idea is that organizational requirements exist in the world and the enterprise system has capabilities that map on to the requirements. The better the mapping the better the system is for the organization.

However, both the capabilities of the system and the requirements are complex and difficult to precisely measure. Specifically, the capabilities of the system and the requirements or needs of the organization can be further subdivided into three categories. Taking each in turn, the capabilities are of three types. Firstly, those that any stakeholder *feels* are relevant at any time during selection. Secondly, those that any stakeholder *perceived* to be relevant at any time during selection. Finally, those that are *actually* relevant at the same point in time. Similarly, the enterprise system has actual capabilities but also the perceived capabilities and those that are actually appropriated by people using the system.

The first step in implementing enterprise systems is finalizing the scope of the system customization and thus determining whether a ‘vanilla’ system be implemented or that some degree of customization is required. The second is ensuring that the system’s capabilities are understood well enough to minimise reliance on perceived capability. Thirdly, it is important for the organization to decide on essential requirement.

Once the system capabilities, scoping, and organizational needs have been identified an analysis follows. Using ideas similar to those in Table 1, the degree of system deficit, completeness, and excess can be identified. However, a contribution to the idea of ontological distance is weighting the differences according to a hierarchy based on the ontology used. This weighting is based on the relative degree of criticality of the term from the ontology with respect to other terms. For example, things are weighted higher than properties. Further, a mutual property between things, a relationship between organizational roles is an example of this, is weighted higher than an intrinsic property, such as whether a manager has a spending limit recorded.

Reference models are good subjects of ontological evaluation. For example, the reference models and processes, functions, and systems output for a Human Resources sub-system would be evaluated against an organisation’s needs. With weighting applied according to the taxonomy proposed by Bunge an assessment can be made as to the suitability of the sub-system through its integrated model representations.

Once the ontological evaluation is completed and weighted then a discussion of the differences and the nature of differences commences. The organization can use the results to decide which enterprise system is selected. Then, during implementation, ontological evaluations using the idea of distance can frame discussions about if and how processes, data models, organizational structure, and outputs can change. If a vanilla implementation is sought then 'the world' must change. If customization is the preferred path, then the nature of customization of the system capabilities can also be openly discussed and determined. The degree of difference and nature of the difference can be quantified. Further work in this area is eagerly anticipated.

5 Reflections, Discussion and Future Challenges

This paper has presented the representational view of information systems as conceived by Weber and Wand (Weber 1997): an information system represents some real-world system. It shows an ongoing program of research, using philosophical ontology, into representation in information systems, particularly into conceptual modeling tools and methods and into understanding enterprise systems implementation and customisation involving many researchers across the world with a concentration in Australia.

The program, having begun by using categories from ontology to assess the constructs in modeling grammars is now examining diverse topics such as how easily people understand models through to ways of assessing the goodness of fit of a specific enterprise system implementation. The program is not without controversy with a recent challenge by Wyssusek (2006) into the veracity of appealing to ontology, and into the shortcoming of not fully utilizing Bunge's ontology.

Apart from two volumes on ontology, Bunge wrote on related areas of philosophy. One was semantics where the meaning of various systems at different levels in his typology were argued to be central. Recent literature is calling for this richness to be included in research (Rosemann and Wyssusek 2005; Rosemann et al. 2004b). Appropriately for a scientific ontology the use of Bunge's richness requires input from the sciences in informing the analysis of the systems themselves. Bunge separates technical systems (cars, computer systems, and pumping systems) from sociological systems (human systems that use technical systems in economics, law, and the arts). However, in recent reproductions (Rosemann and Wyssusek 2005; Rosemann et al. 2004b) there is no separation with 'socio-technical systems' replacing Bunge's clear dichotomy.

The separation is critical in Bunge's philosophy. Sociological systems use technical systems. All of these systems, Bunge would claim, must be described and analysed using science.

It comes as no surprise that information systems are truly socio-technical systems thus calling on sociology to inform information systems as a socio-technical endeavour is important. This underscores the multi-disciplinary nature of information systems involving technical and sociological aspects and the emergent complexity of the interactions between the two is wonderfully described by Allen Lee: "...research in the information systems field examines more than just the technological system, or just the social system, or even the two side by side; in addition, it investigates the phenomena that emerge when the two interact" (2001). The technical artifact itself will play an important representational role. What becomes important is the relationship between actors in the sociological system and technology that allow people to use technology to do something.

This raises the first important question: how catholic is the conceptualization of an information system that represents a real-world system? Does the information system represent a real-world system, or perhaps represent an opportunity to act? Further, the analysis and design of the latter type would involve conceptual modeling using grammars with different representational underpinnings (Johnston et al. 2005) from Bunge's ontology. Specifically, Bunge's ontology, being a scientific ontology, has difficulty in representing purposeful human action (Chisholm 1976; Chisholm 1979). There are going to be limitations as to what sorts of systems an ontological analysis based on Bunge's ontology can be applied. Alternatively, when constructing representations during conceptual modeling other ontological terms may be needed.

To illustrate, in his 1997 monograph Weber states that, in accordance with the definition of an information system, "[a]n electronic mail system provides information about the states and events occurring to the person who sends a message. It provides a representation of these states and events to the receiver of the message" (Weber 1997). Many systems like this one are action-oriented systems. Including conceptualizations and ontologies that are sympathetic to human centred action will advance the discipline's understanding of systems. Bunge's ontology, due to its naturalism, holds no place for a person-centred action or agency. While for traditional accounting or management systems common at the onset of the representational information system research. It is becoming increasingly clear that representational systems are not the only type of information system required. Systems that are used by people to do something rather than to represent something are now commonplace. The email system fits this characterisation. Even a payroll system described by Weber (1997) as providing "… information about changes of wealth for an organization and its employees. It represents claims that the employees have against the organization for provision of services and eventually discharges of wealth that the organization makes to settle these claims." in fact concerns action: paying employees. Researching the implications of an action-centred view of information systems and their representational needs during analysis and design is valuable.

Bunge's view of the world is still going to be an analytical (representational) one from a dispassionate (scientific) viewpoint and not one for other modes of operating in the world. If one is interested in representing *how the world of work is* as seen through science then this is a great way to go. Allowing for representational clarity when building or selecting information systems is important because the technical artifact will be situated with people in an organization. But, not all of these systems assume a 'bird's eye' and dispassionate view of the world one may need to examine other ontological positions where being in the world and acting is important.

This can be achieved by continuing to be open to applying ontological positions other than naturalism. This has occurred in other areas of informatics research (Guarino 2006). Whether these fit within the representational model of an information system or another conceptualization is an important question. Ontological work based on Bunge's ontology and its derivative ontology known as the Bunge-Wand-Weber ontology leads to a conclusion that information systems represent real-world systems. This characterization is heavily influenced by the specific ontology (Bunge's). Other characterizations of information systems are now evident. Ontological analysis is beginning to expand to consider these other characterizations. It is this extension that is now important to address in ontological analysis of information systems.

Another dimension of this openness is taken up in the recent Scandinavian debate by Kalle Lyytinen when he called for plurality in modeling aproaches because "the representation and the reality [are] co-constitutive" (Lyytinen 2006) and that "alternative linguistic systems (grammars) will organise and constitute our world differently (but still retain some fidelity towards the world outside represenations)" (Lyytinen 2006). This is a clear parallel to the need for alternative ontologies that segment or cut up the world differently. (Milton and Kazmierczak 2006).

Many still feel that the program has merit but there are also reasonable limitations to the applicability of this program of research. The role of representation goes beyond the idea of an information system representing a real-world system and rightly include using representations of (the future) reality that will result from building specific technical and socio-technical systems (Smith 2004). Part of that future reality is the resulting socio-technical system and is represented using modeling tools and methods common to information systems. This latter use of ontology to inform the representational quality of models and modeling processes in informatics is an important one for the discipline and one that clearly has a role for a theory of representation.

The program of research begun twenty years ago by Wand and Weber has been a significant one, without which fundamental questions about meta-theories governing modeling grammars and their applications in many contexts would not have been asked. The challenge remains for broader applications of this, and other, theories of what is an information system, and for broader research into theories about the role of representation in designing or customizing information systems. Further, as Wand and Weber have recently restated a plea to follow the “time honored tradition in science—namely, that the validity of theories needs to be tested empirically” (2006).

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