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Abstract

In this paper we present propositions which we have argued elsewhere concerning ontology and data models. Additionally, we present evidence relating to our propositions. We have found that Chisholm's ontology has the potential to be a unifying theory for data models. In addition, our research has lead us to the position that ontologies founded in the philosophical tradition of realism seem to serve the purpose of a unifying framework for data models. Further, we have seen the realistic ontologies by Mario Bunge and Roderick Chisholm used in information systems. We believe that realistic ontologies have a role to play in understanding information systems.

Keywords

IS Design, Database Design, Data Modelling, Process Design

Introduction

Modelling is an integral part of much of human activity. Models provide us with a "laboratory for the imagination" (Starfield et al. 1990) in which we can understand, vary, investigate key properties, or communicate a shared understanding of the artefacts or processes that we are interested in. Further, models allow us to perform such analyses and compare alternatives without going to the expense of implementing the processes or building the artefacts.

In information systems the objective is to build a technological and social system which can process information and record information from a specific domain of interest. In modelling information systems we would ideally like to describe and analyse peoples' perceptions of the domain of interest. Ideally, the modelling process should allow us to understand the proposed system, which encompasses technology, people, and processes, in a way which is meaningful for the people involved and which can be implemented using suitable technology within organisational parameters. The model should be a good predictor of the way that the final system will actually be used.

Our interest in this area has focused on data models which feature prominently in Information Systems. We construct data models in order to understand significant entities in the domain of interest, their relationships with other entities as well as properties possessed by each of the entities. We are interested in finding a unifying framework based upon recognised theory that we can use to discuss and rationalise about data models. Now, there are numerous data models in the literature and, at least superficially, they appear to have some features in common. Any unifying framework will need to discuss the similar and different features of a range of data models using a single set of concepts and terms. One possibility for providing such a framework comes from the philosophical study of ontology (Wand et al. 1995). We go one step further, and suggest that ontologies are useful as a theory with which to analyse data models. As a philosopher understands it, the study of ontologies deals with the 'categorial structure of reality' (Honderich 1995). An ontology also provides a description of fundamental terms, which one uses to describe reality, and the ways in which these terms relate to the categories. In these ontologies basic questions are asked concerning the make up of reality and what fundamental categories of things exist and the terms that one needs to construct a description of a 'state of affairs'. Data models similarly have terms used to describe a state of affairs.

Recently there has been considerable research utilising the ontology by Mario Bunge (Bunge 1977; Bunge 1979) to examine systems analysis and design methodologies (Wand and Weber 1989; Wand and Weber 1990; Wand and Weber 1993; Weber 1997; Wand 1996; Rohde 1995) and some of this research has investigated data models (Wand et al. 1993; Weber and Zhang 1996). Wand et. al (1995) mention three specific limitations of using Bunge's ontology in considering conceptual modelling. We paraphrase them here. Firstly, there is no ontology that is generally accepted. Secondly, that ontological models seem to assume an objective reality, while the world is only known through human perceptions. Thirdly, the specific model selected by

Wand and his colleagues does not deal with the organisational and behavioural aspects of information systems. We have selected an ontology using criteria that take into account the purpose of data modelling and the human factors mentioned and so goes part the way to addressing the limitations mentioned. Further, we have conducted ontological studies of five representative data models using the selected ontology by Roderick Chisholm (Chisholm 1992; Chisholm 1996). Our position is summed up in the following propositions which we have explored previously in Milton et al. (2000).

Proposition 1: *Ontology provides a theory upon which to base a unifying framework for data models.*

Proposition 2: *Chisholm's ontology can be used as a unifying framework in which to compare, contrast and investigate different data models.*

In this paper we provide evidence to support these and raise questions about the use of realistic ontologies in information systems.

Ontology as a Unifying Framework for Data Models

In this section we explore our first proposition and construct a method by which an ontology can be used with data models:

Proposition 1: *Ontology can provide a theory upon which to base a unifying framework for data models.*

We begin by trying to understand ontology from a philosophical viewpoint, and then argue that each of the data models considered in our studies possesses ontological elements. A good explanation of ontology can be found in (Honderich 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 categorical structure of reality. … Different systems of ontology propose alternative categorical schemes. A categorical scheme typically exhibits a hierarchical structure, with 'being' or 'entity' as the topmost category, embracing everything that exists".*

A system of ontology provides us with a set of terms for discussing the nature of existence and the categories making up reality to which terms are related. Through its terms, an ontology can be used to create an abstraction from reality.

Data models also provide us with terms with which to build models of reality, for example, OMT (Blaha and Premerlani 1998) uses terms including objects and associations, ER (Chen 1976) uses entities and relations, and FDM (Shipman 1981) uses entities and functions. Models of reality that are possible in a specific data model are composed of the terms provided by the data model. Data models, however, do not attempt to form taxonomies in which to describe reality, nor do they seek to embrace everything that exists. They do, however provide us with a framework for constructing models of reality. There is at least a superficial similarity between data models and ontologies.

Further, each term is given meaning through an associated concept. The world view implicit in a data model, or an ontology, is expressed through the concepts that give meaning to terms. For example, ontologies and data models often discuss attributes. 'Attribute' has an associated concept that reveals the specific meaning behind 'attribute' for a data model or an ontology. The concept that refers to the term 'attribute' may be different in each. A specific data model, may see attribute as applying to a 'class of entities' (more terms and concepts) or that each entity in a specific class must exhibit the same set of attributes.

In contrast, an ontology may see a specific attribute as being exemplified by many different 'individuals' (another term that is probably related to entity), and that different individuals may exemplify the same attribute simultaneously. Clearly, for the same term 'attribute', there is a degree of synonymity in the concept when used in the context of a data model and in the context of an ontology, but there is also a myriad of nuances that distinguish 'attribute' in a data model from the use in an ontology. The world view in a data model or in an ontology is contained in the totality of terms and concepts for each.

Some ontologies contain terms that are appropriate for analysing data models. Others will not be appropriate because of the terms and categories defined. Consequently, the selection of an appropriate ontology is important to our study. We need to select an ontology that discusses elements of a similar nature to data models and thereby can be used to analyse and rationalise about data models. We have selected an ontology by Roderick Chisholm on this basis (Chisholm, 1992; Chisholm, 1996). Before we describe the selected ontology, we develop the method that can be used with a selected ontology.

A Method for Comparison

To conduct an ontological comparison, we use the ontology as a benchmark against which each framework can be evaluated. We also learn about the utility of an ontology as theory. The chosen ontology presents us with a view of reality. We begin by selecting concepts from the ontology which are relevant for the comparison, and form the basis for the comparison. We then perform a pairwise comparison of each data model with the ontology based upon the chosen concepts. In conducting the pairwise comparisons we are testing each framework against the selected and independent view of reality.

The pairwise comparison allows us to find a qualitative and relative 'goodness of fit' of the framework with the ontology, and consequently the 'goodness of fit' with the benchmark.

We use a series of graded indicators of agreement to represent the relationship between concepts from the ontology and data models. We base the indicator on Umberto Eco's semiotic theory, particularly the theory of codes (Eco 1976) and the idea of coverage of semantic field. Eco's theory unifies disparit applications of semiotics and it has a diverse range of applicability (Eco, 1976). This theory allows us to explain the relationship between the ontology and each data model since each has terms with associated concepts that serve to be analogies to sign and content. We have argued such a relationship at length (Milton, 2000; Milton and Kazmierczak, 2000) but space constraints preclude us from describing the complete analysis technique here. Interested readers can find a complete description of the method and results in (Milton, S.K., 2000). Interested readers may also see a preliminary presentation of results in (Milton et al. 1998). Previous comparisons of data models are not ontological by nature, such as the surveys in (Hull and King 1987; Peckham and Maryanski 1988).

In each pairwise comparison, the researcher conducts a 'mind experiment' in which a comparison of each data model with an ontology occurs. We need to be able to convey succinctly what we have found, and consequently, we seek an indicator that shows the degree of the overlap between the semantic fields covered by concepts in the ontology and the semantic fields covered by concepts in the data models. It is critical to be aware that the indicator shows the nature of the overlap as the researcher sees it, and that it must be accompanied by an explanation of the results so that the nature of the coverage is justified.

Suppose we have a concept *c* (from the ontology) and a specific data model. There may be three broad categories of results.

Firstly, the data model may have total overlap with respect to *c*. Total overlap may be provided by one concept (for example, *d*) or perhaps by several concepts (for example, *d* and *e*).

The second possibility is where the overlap is partial and in this case it may be possible to extend the concept from the data model to support the full generality of the concept from the ontology. It may also be the case that there is little prospect for extension due to certain concepts in the data models being contradictory with respect to the ontology in ways that make extension difficult.

Finally, it may be that there is no overlap at all between the data model and *c* from the ontology in which case we have the same options as in the partial case above.

Gaps in the coverage of the semantic field described by a concept from the ontology occur where either no coverage is evident or where partial coverage of the semantic field described by the concept is evident. The gap in these cases can mean one of two things.

Firstly, it could mean that there is no concept (or part of a concept) from the data model that has coverage in any way over the gap in the semantic field concerned. In this case, extension of the data model is likely to be relatively straightforward, although deeper analysis is required to determine the ease with which extension can occur.

Alternatively, it could be that there is a concept from the data model that doesn't span the 'gap' in the semantic field, but instead spans a different semantic field that is contradictory (Eco 1976) with respect to the original semantic field from the ontology.

We present our results in the next section after introducing the ontology we have selected.

A Unifying Framework for Studying Data Models

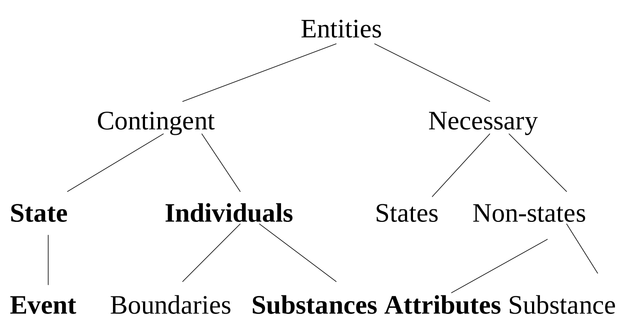
In this section we explore the following proposition and provide evidence to support it:

Proposition 2: *Chisholm's ontology can be used as a unifying framework in which to compare, contrast and investigate different data models.*

We begin by discussing the commonsense realistic ontology (Dancy and Sosa 1992) proposed by Roderick Chisholm. It is difficult, if not impossible, to describe an ontology in a short space and so we concentrate on a few key aspects. The categories in Chisholm's ontology are organised into a taxonomy which is shown in figure 1. The theory proposed by Chisholm divides the world into entities that are 'contingent' and don't have to exist, and 'necessary' entities that must exist in order for his theory to be consistent. We concentrate on the boldface categories highlighted in the figure below as these are also typical of many systems.

Chisholm's ontology centres on individuals and the attributes they exemplify. Chisholm stresses that attributes are fundamental to his ontology. As we will see later, he reduces other terms by defining them using only attributes. The terms and associated concepts of 'individual' and 'attribute' have descriptions that show not only their individual disposition, but also their roles in sets, classes, and relations. We also describe these below. These terms are not fundamental to the ontology but nevertheless are important terms that are discussed in making sense of 'what there is' and are appropriate for our goals.

Figure 1: Chisholm's Categories



Individuals are discernable and transient objects and need not be material (or physical) in nature. Examples of individuals are an accountant named Freda, the annual financial statements for Ericsson, and Orly International Airport. Individuals are identified by using the attributes that only they exemplify. Further, individuals may have constituents thereby giving them structure. Constituents may be other individuals (called parts) or may be boundaries (the other constituents). For example, consider Orly Airport. It has several rent-a-car franchises, bars, restaurants, departure gates, each of these are parts of Orly Airport and are also individuals. In this example, most of these can be further sub-divided.

Individuals may exemplify attributes. Orly Airport is very busy; Nokia's balance sheet is good; Freda, our accountant, is of age 43. Some attributes may never be exemplified and others cannot be exemplified. For example, Orly Airport may never be green. We can be sure that Orly Airport can never be liquid. Chisholm also allows for compound attributes which may consist of other compound attributes or simple attributes. He suggests that an attribute may be the conjunction or disjunction of several attributes. For example, the attribute of 'being good' with respect to Nokia's financial statements may be the conjunction of being in surplus (profit) and being of good credit rating.

In Chisholm's ontology, attributes are used to restrict membership of sets and classes. Further, Chisholm reduces discussion of classes to discussion of attributes. Specifically, this is achieved by adopting Russell's reduction of classes to attributes (Russell 1908). This has the effect of building classes and sets from individuals through the exemplification of attributes and not by constructing elaborate class structures. For example, suppose we are maintaining a taxonomy of plants. Periodically, the taxonomy may change quite drastically without a change in the majority of attributes exhibited by the plants involved. Using Chisholm's ontology the membership of classes can change radically because membership criteria is based on attribute exemplification.

Classes and sets can be selected based upon attributes that are conjunctions and disjunctions of other attributes, and in this sense complex class relationships can be realised. The central point remains, that individuals come together to form classes and are fundamental to the ontology

Relations may exist between individuals but relations, according to Chisholm, are unidirectional and not necessarily reciprocated. Further, relations are defined in terms of attributes by reducing relations to ordered pairs of attributes. For an ordered pair to represent unidirectional relations, attributes that uniquely describe each individual need to be found. For example, suppose that Freda (our accountant) is recruited to audit Nokia's books then an attribute being an ordered pair of identifying attributes for Freda and Nokia would have to be exhibited by Freda. A summary of these key ideas is given in table 1.

Table 1: Concepts for Statics in Chisholm's Ontology

Concept	Description
Individual Core	Chisholm allows for discernible and transient objects. These are called individuals. Individuals come into being (are created) and pass away (destroyed). In this sense they are transient.
Identity	Each individual possesses an attribute (or several attributes) that uniquely identifies it.
Structure	Individuals may have constituents. These are either other individuals (known as parts) or boundaries (the other constituents.) Individuals that make up parts of others are still thought of as being individuals.
Attribute Core	Attributes are exhibited by individuals. They are central to Chisholm's ontology, after individuals. Further, attributes are enduring, in the sense that they don't come into being and don't pass away. Further, attributes must be loosely coupled with individuals.
Equivalence	Attributes can be equivalent in the sense that if something exhibits one attribute then it exhibits the other.
Complexity	Attributes may be simple or complex. Complex attributes are combinations of either simple or other complex attributes. The mechanism suggested by Chisholm is one involving conjunction and disjunction of attributes. He feels there may be other ways of providing for this complexity.
Classification Core	Classes and sets are provided using attributes, in the ontology. Specifically, it is through the attributes that membership of classes is determined.
Relation Core	Individuals may be related. Specifically, relations are attributes (an ordered pair). The ontology requires that attributes that identify the participating individuals are required. The relations are unidirectional (not bidirectional).

Results

We have considered five data models in our investigations using the method described earlier: the Entity Relationship Model (ER), the Functional Data Model (FDM), NIAM (Nijsen and Halpin 1989), the Semantic Data model (SDM) (Hammer and McLeod 1981) and OMT as it pertains to the Unified Modelling Language (UML). We have conducted a comparison between these data models and Chisholm's ontology and have discovered that there is a good degree of fit. A summary of the findings is given in table 2 below. In the table we use a √ to indicate full support for a feature of Chisholm's ontology, a $\surd_p$ to indicate qualified support for a feature in Chisholm's ontology and an X to indicate no support for a feature in Chisholm's ontology. The features chosen from Chisholm's ontology are the key static features.

The indicative results in Table 2 show a good degree of coverage for a number of core concepts from Chisholm's ontology by all data models. However, each data model possesses some concepts for which there is only partial or qualified support in Chisholm's ontology. Due to the constraints of space we can only give a brief summary of the results in this paper and the reader is referred to (Milton et al. 1998) for a more detailed analysis.

Chisholm's ontology views the world as a collection of individuals and relations between them, and the ontology uses attributes to describe both individuals and relations. Attributes are universals and endure, and, consequently they are loosely coupled with individuals.

Table 2: Results of the Comparison of Selected Data Modelling Frameworks Using Chisholm's Ontology

Ontological Concept	**ER**	**FDM**	**SDM**	**NIAM**	**OMT**
Individual	$\surd_p$	$\surd_p$	√	$\surd_p$	√
Core	√	√	√	√	√
Identity	√	√	√	√	√
Structure	X	$\surd_p$	√	X	√
Attribute	$\surd_p$	$\surd_p$	$\surd_p$	$\surd_p$	$\surd_p$
Core	$\surd_p$	√	$\surd_p$	√	$\surd_p$
Equivalence	X	X	X	X	X
Complexity	$\surd_p$	√	√	$\surd_p$	√
Classification	$\surd_p$	√	$\surd_p$	$\surd_p$	$\surd_p$
Relation	$\surd_p$	√	√	$\surd_p$	$\surd_p$

Attributes are also used to determine class and set membership. Our comparison suggests that this is to a large extent a similar world-view as those imparted by the data models and there is a good level of agreement with the ontology and the modelling frameworks that we have studied. On the other hand the data models lack the full generality of Chisholm's ontology. The major departures from Chisholm are in the nature of relations and attributes and the implications of a tighter coupling between individuals and attributes in the data models; particularly as these pertain to sets and relations which are primitive in the data models.

Classification in the ontology is evident through the attributes exemplified by members of classes. In the ontology, classes are related to each other by the intersections and unions of the attributes used to select them and thereby can simulate class hierarchies. This approach is entirely different from most classification approaches used by data models and also different from the rich and rigid class hierarchies that are prevalent in some data models.

The consequence of these departures from the ontology is that it is likely one can model a narrower range of situations using the studied data models than Chisholm's ontology, although this requires further investigation. Further, Chisholm's ontology has the potential to change our view of data modelling by its increased flexibility achieved through bidirectional relations and through its loose-coupling of attributes with respect to individuals. In turn, this has positive implications for the flexibility of models which are subject to radical or ongoing change. It is the formation of classes through attributes as a direct consequence of loose coupling that is of most beneficial for flexibility.

We have found that ER, OMT's Object Model, and NIAM do not support such class flexibility. This is principally because of tight coupling between individuals and attributes found in ER, OMT's Object Model, and by practice in NIAM.

We found that FDM captures the fundamental nature of Chisholm's ontology more closely than the other modelling frameworks and, due to its evident simplicity, has more potential to be able to support other elements presently not supported that are directly related to loose coupling of attributes and individuals and to classification. Its simplicity means that there are few, if any, concepts in FDM that are antonymous with respect to concepts from the ontology in either a contradictory or contrary manner (Eco, 1976).

We have also found SDM to be reasonably close to the ontology. SDM's complexity with respect to its class system makes it a difficult modelling framework to use to fully express Chisholm's ontology. Nevertheless, it would be interesting to investigate SDM further.

Concluding, we can see from the results that the modelling frameworks share, to a large degree, the world view of the ontology. Consequently there is good reason to believe that Chisholm's ontology can serve as a unifying framework in which to explore these data models. The areas of departure tend to be of the nature of a difference in overlap with the modelling frameworks rather than complete absence of support. Also, all concepts have a high degree of coverage with respect to their core. There are, however, some issues that need investigation. The area of most concern is that of classification. Clearly, the rigidity of class construction and the presence of rigid class hierarchies is not supported in the ontology. As implementation efficiencies this rigidity may be acceptable. As modelling features there appears to be little support in traditional realistic philosophy for such an approach.

Discussion and Future Research

Each ontology that one considers assumes definitions, and uses terms, that are steeped in the western philosophical tradition (Flew 1989), and the attitude taken by the author of an ontology to certain key questions reveals his or her philosophical outlook. This outlook is also expressed in terms with deep philosophical meaning (Kim and Sosa 1995; Audi 1995; Honderich 1995; Dancy and Sosa 1992).

Chisholm's ontology adheres to 'critical commonsensism' (Chisholm 1996) and is also an example of 'extreme realism' (Chisholm 1996). Together it means that Chisholm's ontology is one of commonsense realism.

> *"Realism in any area of thought is the doctrine that certain entities allegedly associated with that area are indeed real. Common sense realism says that ordinary things like chairs and trees and people are real. Scientific realism says that theoretical points like electrons and fields of force and quarks are equally real." (Dancy and Sosa 1992)*

Commonsense realism is also a realism that explicitly recognises the role of human perception in understanding reality (Smith 1995) while still allowing for a scientific explanation of reality. Now, the only other major ontology recognised in Information Systems is the realistic ontology by Bunge, although we may say that the realism of Bunge's ontology tends towards scientific realism. Thus, the ontology we selected for our study and Bunge's ontology are both realistic. Is there something about realistic ontologies that are particularly suited to data modelling?

The two key terms of Chisholm's ontology are 'individual' and 'attribute', that is, that individuals exist in reality and that these individuals can be described by the attributes that they possess. Attributes and individuals form the realistic core of Chisholm's ontology and both terms are present in related realistic ontologies. In the section above we have argued that most data models possess concepts which overlap with these two fundamental terms and so it may be conjectured that data models tend to Chisholm's brand of realism.

In information systems modelling more broadly we need the capacity for analysing processes, in order to understand and model organisational processes and change. Chisholm's ontology has the capacity to model state, changes in state, and processes. It does this through the related categories of event and state. Further, Chisholm's ontology allows for enduring events that others may call processes.

There are two points to make here. Firstly, we believe that there is potential in the dynamics of Chisholm's ontology for understanding processes, however, we haven't specifically studied this aspect of the ontology in great detail and it will require further investigation. Secondly, we have not yet fully investigated the heritage of the terms state and event and so cannot say for certain that they figure prominently in realistic ontologies. In contrast, we are sure there is a realistic core to the statics of the ontology.

The comparison we have undertaken and the degree of overlap we have found indicate that Chisholm's ontology has the potential to be a unifying framework for data models. Together with related research we observe that two realistic ontologies have now been applied to information systems in a role as theory either of a predictive or unifying nature. The two ontologies, by Mario Bunge and Roderick Chisholm, represent different styles of realism. Bunge's ontology is one of realism tending towards scientific realism whereas in contrast, Chisholm's ontology is one of commonsense realism. We believe that on the basis of these bodies of research that realistic ontologies have a significant role to play in theorising about information systems generally and data modelling specifically.

We conjecture that Chisholm's ontology will be useful in understanding modelling phenomena that are related to the application domain of information systems design in which social or human issues dominate, because it is one of commonsense realism. In contrast, that Bunge's ontology will prove better adapted to the implementation environment or to the application domain of information systems development when human or social issues are absent. An interesting avenue for future research is to study the relationship between the two ontologies and to attempt to capitalise on the strengths of each ontology.

In information systems, there is no doubt that theory must be researched in relevant practical situations so that it can be evaluated. This has been done to an extent with Bunge's ontology. We are currently executing a project involved in validating Chisholm's ontology in case studies and focus groups with experienced data modellers from industry.

It is yet to be seen if ontologies of the type studied have a lasting effect on information systems theory and practice. It is important to explore the role of ontology in information systems theory so that its limitations and applicability can be explored.

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