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Conceptual Modeling and the Quality of Ontologies: A Comparison between Object-Role Modeling and the Object Paradigm

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Abstract

Ontologies are key enablers for sharing precise and machine-understandable semantics among different applications and parties. Yet, for ontologies to meet these expectations, their quality must be of a good standard. The quality of an ontology is strongly based on the design method employed. This paper addresses the design problems related to the modelling of ontologies, with specific concentration on the issues related to the quality of the conceptualisations produced. The paper aims to demonstrate the impact of the modelling paradigm adopted on the quality of ontological models and, consequently, the potential impact that such a decision can have in relation to the development of software applications. To this aim, an ontology that is conceptualised based on the Object Role Modelling (ORM) approach is re-engineered into a one modelled on the basis of the Object Paradigm (OP). Next, the two ontologies are analytically compared using the specified criteria. The conducted comparison highlights that using the OP for ontology conceptualisation can provide more expressive, reusable, objective and temporal ontologies than those conceptualised on the basis of the ORM approach.

Keywords: Ontology, Ontology Engineering, Ontology Quality, Conceptual Modelling Paradigms, Object-Role Modelling, Object-Paradigm, Perdurantism, Endurantism.

1 INTRODUCTION

Ontology research has attracted increasing attention in information systems design and development (Wand and Weber 2002; Fonseca 2007). In this context, ontologies are recognised as a useful means for achieving semantic interoperability between different systems. This is because ontologies can capture semantics of information systems to facilitate shared understanding between different parties (Ouksel and Sheth 1999). The weight of ontologies however comes from the fact that they are considered important backbones for many organisational applications in areas including, but not limited to, knowledge engineering, information integration and software development. In addition, they are highly significant for the Semantic Web and Semantic Web services (AL Asswad et al. 2009). Hence, information systems that make use of explicit and formally defined ontologies have been described as ontology-driven systems (Guarino 1998).

Simply put, an ontology is an "engineering artefact" (Guarino 1998) representing a particular phenomenon or domain of knowledge. Ontologies are generally composed of concepts, relations between these concepts and axioms to restrict the interpretation of concepts and are (ideally) precise, machine-understandable and signify shared representations of real world phenomena. Consequently, it is important that ontologies are of a good quality, in order that they serve their intended purposes and be shared as well as reused by different applications (Guarino 2004). The quality of ontological models can be evaluated based on the models' semantic preciseness and richness; that is, the extent to which the ontology is describing a particular phenomenon abstractly, but accurately and meaningfully. Retrospectively, the quality of ontologies is heavily based on the adopted engineering methodology (Nicola et al. 2009) where conceptualisation (i.e., creating conceptual models) is a significant activity (Uschold and King 1995; Al-Debei and Fitzgerald, 2009). Conceptual modelling is "the activity of formally describing some aspects of the physical and social world around us for the purposes of understanding and communication" (Mylopoulos 1992 p. 389).

In this paper, we place an emphasis on conceptual modelling paradigms and their impact on the quality of the developed ontologies. In line with Jarrar et al. (2003), we argue that developing a qualified ontology is strongly based on the conceptual modelling paradigm employed. There are two reasons for this position: (a) Conceptual modelling can be seen as a tool to analyse the structure of a given reality (Guarino 1998); and (b) paradigm modelling constructs are utilised to represent the required ontology. For example, Jarrar et al. (2003) argue that the decision to model a concept as a class or a property is based on the employed conceptual modelling paradigm. Therefore, extra care must be taken in order to clearly define objects' identities in the sense of clarifying their distinctive features; the more issues about objects (e.g., relations and instances) that are considered during conceptual modelling, the more the potential for a richer and more accurate conceptualisation (Spyns et al. 2002).

Modelling paradigms can generally be classified as three-dimensional (i.e., endurantism; for example, Object-Role Modelling (ORM) and Object-Orientation) and four-dimensional (i.e. perdurantism; for example, the Object Paradigm (OP)) approaches. These paradigms perceive real-world phenomena from different philosophical standpoints, thus allowing different conceptual models to be produced. This paper aims to demonstrate the quality variations in ontologies across the two modelling paradigms (three-dimensional vs. four-dimensional), by utilising the ORM and OP approaches as representative cases. To this aim, a bookstore ontology conceptualised on the basis of ORM is re-engineered into an ontology modelled according to OP to highlight differences.

The remainder of this paper is structured as follows. Section 2 provides a theoretical background relating to ontology, ontology engineering and conceptual modelling paradigms. Section 3 explains the research design. Section 4 demonstrates the re-engineering process and provides a comparison between the models to show advantages and deficiencies of the two models. Section 5 discusses the significant implications for both theory and practice. Last the conclusions are presented.

2   THEORETICAL BACKGROUND

2.1   Ontology and Ontology Engineering

Ontology is a term that originated in philosophy and refers to the systematic explanation and study of the nature of existence, or being (Chandrasekaran et al. 1999). The term has been subsequently borrowed by the information systems and computing disciplines (e.g. Wand and Weber 1990; Guarino and Welty 2002) and changed somewhat. For example, Gruber (1995) argues that the philosophical ontology limits the ontological representation to class definitions and taxonomies; thus more constructs such as axioms are required to constrain the interpretation of defined concepts.

Basically, ontology is a constructed model for a particular domain representing a real-world phenomenon. In computational terms, an ontology is most commonly defined as a formal explicit specification of a shared conceptualisation (Gruber 1993). Fundamentally, conceptualisation implies abstraction, which signifies that ontology represents only knowledge regarded as core in any specific domain. So, in practice, computational ontology provides a definition of concepts, axioms, and their properties in a formal, precise and shared format (Jasper and Uschold 1999).

Ontology engineering is a subfield that covers issues related to ontology development and use throughout its life span (Gomez-Perez et al. 2004). Ontology development covers a set of activities conducted during conceptualisation, design, implementation and deployment phases (see Devedzic 2002). There are few approaches or methodologies for constructing ontologies however (e.g., Gruninger and Fox 1995; Fernandez-Lopez et al. 1999; Al-Debei and Fitzgerald 2009). Pinto and Martins (2004), for example, argue that the ontology engineering process is composed of the following five phases: specification, conceptualisation, formalisation, implementation, and maintenance; whilst Uschold and King (1995) report four main stages for ontology development: identifying purpose, building the ontology (ontology capture, ontology coding, and integrating existing ontologies), evaluation, and documentation. Irrespective of any differences among existing methodologies, however, they all regard conceptualisation as a major activity in ontology engineering.

2.2   Conceptual Modelling Paradigms

Conceptual modelling paradigms can be categorised into three-dimensional (endurantism) and four-dimensional paradigms (perdurantism). Endurantist paradigms such as ER (Entity-Relationship), OO (Object-Oriented) and ORM (Object Role Modelling), assume that objects have three spatial dimensions and are wholly present at each moment of their lifetime (Hales and Johnson 2003). Endurantist conceptual modelling is widely used in areas such as database design and information systems development and have also been utilised within ontology development (Jarrar et al. 2003).

Perdurantist approaches, such as OP, assume that objects have four dimensions (spatial and temporal) and just partly exist at each time instant of their life span (Hales and Johnson 2003). Unlike endurantist paradigms, semantics that are embedded in changes of time are considered by perdurantist paradigms as a core aspect of the approach. Perdurantist conceptual modelling has been proved useful in areas such as database design (Erwig et al. 1999), systems analysis and design (Parent et al. 1999), geographic information systems (Xu et al. 2006) and ontology engineering (Partridge 2005).

The main difference between both of these approaches lies in their underlying philosophical foundations. The consideration of spatio-temporal extensions of any object in any perdurantist paradigm intrinsically represents temporality, whilst those based on endurantism do not take this extension into consideration. Indeed, endurantist approaches are pre-equipped to deal with spatial extensions only, but require fundamental changes to be able to deal with temporality. Furthermore, in perdurantist approaches the identity of each object is clearly defined, which is not the case in endurantist approaches as they assume that an object is completely existent at any one point in time. For example; if two real-world objects have the same attributes and attribute values in OO (taken as an endurantist approach) then they are recognized as the same object. But this is not true for perdurantist approaches such as the OP as the objects may have different temporal extensions.

In explaining these differences in more details, we present ORM as a representative of endurantist approaches and OP as an example of perdurantist paradigms and briefly explain the reasons for choosing these two approaches.

2.2.1 ORM (Object Role Modelling)

ORM is a conceptual paradigm for modelling and querying information systems. Natural language and diagrams are used in ORM to represent a phenomenon (Krogstie et al. 2007: p.23). ORM depicts a reality using objects (entities having values) that play some roles to participate in relationships (Halpin 1998). An ORM model can therefore be depicted as a network of entity and relationship types representing a specific domain. Entities can be lexical (i.e., utterable), such as 'colour' and 'name', or non-lexical (i.e., unutterable), such as 'car' and 'man' (Jarrar et al. 2003) – though such a classification is based only on linguistic distinctions. ORM allows the definition of subtype and whole-part relationships. Constraints such as asymmetry, cardinality and intransitivity can be also specified in ORM models. To clarify the main modelling constructs in ORM, consider the following simple example: a man is driving a car. The concepts 'man' and 'car' are both considered as entity types in the ORM notation. A 'man' has a role in that he *drives* a 'car', while a 'car' has a role of being *driven by* a 'man'. In contrast to other three-dimensional modelling paradigms, ORM does not use attributes, although relationships are used to indirectly represent attributes. For example, the 'continent' attribute of a 'country' entity is represented as a relationship 'a country is *located in* a continent' where '*located in*' is the relationship.

One can argue that ORM has some advantages over other endurantist paradigms (e.g., Halpin and Bloesch 1998; Jarrar et al. 2003) in that: (1) It enables easy and effective definition of constraints because imposing constraints on relationships is easier and more effective than on attributes; and (2) the use of relationships only can eliminate the confusion caused when taking a decision in OO or ER to model something as a relationship or an attribute. Moreover, dominant logic-based ontology representation languages, such as OWL, provide ontological constructs for modelling properties as relations only and not as attributes. Subsequently, translating ORM-based conceptual models into OWL, for example, is more natural and a less confusing process than the translation from ER or OO into OWL.

2.2.2   OP (Object Paradigm)

Having recognised the importance of the temporal dimension in modelling, proposals have been developed for more naturally incorporating this dimension into conceptual modelling. To give just a few examples: More et al. (2001) and Hadzilacos and Tryfona (1997) add temporal semantics to OO and ER respectively; Allen et al. (1995) present a spatiotemporal model for explicitly modelling temporal aspects of Geographic Information Systems (GIS); and Worboys (1994) proposes a framework for modelling spatiotemporal data using two spatial and two temporal extensions. These frameworks suffer from some or all of the following however: (1) being application-dependent and thus limited in their general usefulness; (2) lack of identification and clarification of the modelling constructs and their use; (3) being theoretical proposals that have not been tested empirically; and (4) being mathematically-based and not focused towards conceptual modelling design.

The Object Paradigm (OP) proposed by Partridge (2005) has advantages in the area of ontology engineering over the other perdurantist approaches because it: (1) Provides holistic modelling constructs that are suitable for ontology conceptualisation; (2) offers detailed ontological modelling guidelines through the BORO (Business Object Reference Ontology) flowchart; and (3) creates patterns for modelling frequently occurring problems such as geographic areas and naming patterns. In order to provide clear referencing to things in the world, OP considers everything as objects where the object identity is a key factor for distinguishing objects from each other. Object identity is defined as an object's spatio-temporal extension in the universe. For example, a book identity is defined by its three spatial dimensions that this particular book occupies in the space in addition to its temporal dimension which is represented by the book overall life span.

The ontological constructs used in the OP can be classified as: (a) Individuals; (b) classes; and (c) tuples (Partridge 2005). Individuals can be depicted as four-dimensional things that persist through time. In other words, individuals are perceived as particular objects that cannot be further instantiated, such as 'John Smith' and 'Adam Smith' being individuals of a 'People' class as an example. Tuples are relations (properties) between individuals. For example, 'Adam Smith' *is son of* 'John Smith'. Classes are types of individuals (classes of objects) such as 'People', or types of tuples (classes of tuples). An example of a class of tuples can be the 'is son of' tuple type which represents all the 'is son of' tuples between sons and fathers. A class extension is the sum of extensions of its members.
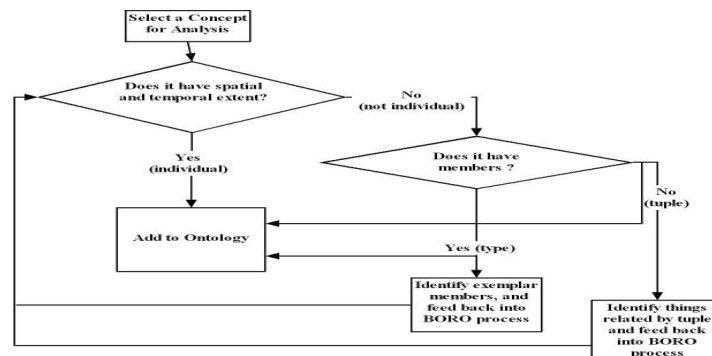

Figure 1.   BORO Flowchart (Partridge 2001)

Importantly, the OP considers the semantics of changes happening to objects. Changes in OP can be modelled through 'states' and 'events'. States are considered as temporal parts of individuals. An example is the 'father' state of the individual 'John Smith' as 'John Smith' could go through many states over time. Events are types of individuals that do not persist over time as they just happen. An example of an event is the 'birth of Adam Smith' which initialises the father state of 'John Smith'.

Partridge (2001) developed a systematic methodology for modelling ontologies based on the OP (see Figure 1). The methodology is called BORO (Business Object Reference Ontology). It guides an ontology modeller during the process of analysing the phenomenon under consideration. This methodology is explained as follows: (a) A concept is selected for analysis; (b) if this concept has spatial and temporal extension then it is an individual, otherwise, it is either a class or a tuple; this object is (c) a class when it can be instantiated or (d) a tuple when it can not be instantiated.

3   RESEARCH DESIGN

This paper utilises a bookstore ontology that is modelled using the ORM approach. This ontology is then re-engineered according to the OP with the aim to analytically delineate the impact of the conceptual modelling paradigm on the quality of the developed ontologies. While ORM is used here to represent endurantism, the OP is used to represent perdurantism. The first issue needing to be tackled is that of answering the question relating to the definition of 'semantic quality' in the context of ontologies. To this aim, we analysed and synthesised the relevant literature (Gruber 1995; Gomez-Perez 2001; Wand and Weber 2002; Shanks et al. 2008) and established a set of criteria which are considered important pertaining to the quality of ontologies:

- **Expressiveness**, which is the ability to faithfully conceptualise the relevant details of a particular domain and represent them in an understandable and unambiguous manner.
- **Temporality**, which is the ability to track changes of ontology objects over time.
- **Extensibility**, which is the ability to expand the ontology gracefully in order to be able to cope and capture future needs.
- **Objectivity**, which is the ability to produce conceptualisations of ontologies in a smooth, managed and guided way. This criterion refers to the existence of techniques and methodologies that could guide modellers during the conceptualisation phase of ontology development in order to reduce modelling errors and confusions.

An existing and published bookstore ontology was chosen as a basis for re-engineering (see Jarrar et al. 2003). This ontology was chosen for the following reasons: (1) The ontology is modelled using one of the endurantist paradigms (i.e. ORM) and thus can be re-engineered into perdurantism; (2) the use of the bookstore ontology is simple and understandable by a general audience; (3) the journal paper that the ontology is derived from is highly cited; and (4) the main focus of the selected paper is conceptual modelling for ontologies and so consistent with our main objective. The re-engineering process is led by a set of competency questions that show the deficiencies of the existing ontology however – this is a reasonably accepted technique that is useful when (re-)engineering ontologies (Gruninger and Fox 1995; Uschold and King 1995). The BORO flowchart was followed in translating the ORM ontological model into an OP ontology. Further, we applied the established quality and evaluation framework to analytically compare the two ontological models showing their competencies and drawbacks. Based on this comparison exercise, the implications of this paper for theory and practice are clarified.

4   ILLUSTRATIVE   CASE: RE-ENGINEERING   A   BOOKSTORE ONTOLOGY

Jarrar et al. (2003) modelled a bookstore ontology based on the ORM paradigm according to the domain knowledge presented in Table 1. The resulting ontology is shown in Figure 2. This ontology has three unutterable entity types – 'Product', 'Book' and 'Price' - and five utterable entity types – 'ISBN', 'Title', 'Author', 'Value' and 'Currency'. The decision to model an entity as an utterable (lexical) or unutterable (non-lexical) entity is merely based on a linguistic distinction. The `ISBN' is used as an identifier for the book concept as the authors assume that it is unique for all instances of a specific book (as is common). This identifier is indicated by a dot at the book oval in Figure 2. Roles are represented as rectangular boxes in the ontology.

Term1	Role	Term2
Book	Is_A	Product
Book	Has	ISBN
Book	Has	Title
Book	WrittenBy	Author
Book	ValuedBy	Price
Price	Has	Value
Price	Has	Currency

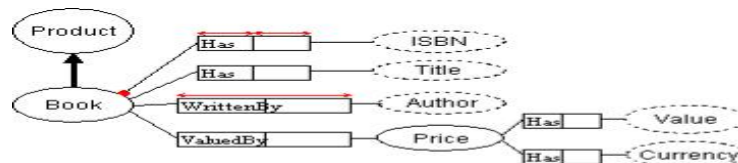*Table 1. Bookstore ontology base (Jarrar et al. 2003)*

Figure 2. ORM Bookstore ontology (Jarrar et al. 2003)

In analysing and examining the ORM bookstore ontology using the established criteria, it is apparent that it does not faithfully express some important domain details. The key issue here is how well the ontology represents reality and whether it represents reality precisely or not, which can be examined using the following competency questions.

Q1.1 How many editions of a certain book have been published?

Q1.2 Who are the authors of a specific edition of a certain book?

Q1.3 How many copies of a certain edition have been produced?

Q1.4 What is the ISBN of a certain edition of a specific book?

The ORM ontology provides no answers to the above questions as it assigns different roles directly to the 'book' class which is considered as a subtype of 'product' class. According to the OP, the examination of the temporal and spatial extensions of the book concept leads us to differentiate amongst books, book editions, and their copies. Arguably, this is more consistent with real world books since a book may have more than one edition, each with a different ISBN. A new edition of the same book could also have a different title. Moreover, a different set of authors can participate in writing different editions of the same book and each edition normally have more than one copy.

Retrospectively, and to capture reality more accurately, we re-engineer the ORM ontology and add both 'BookEditions' as well as 'BookCopies' to the OP ontology. Basically, the 'Books' class is modelled as a composition of its 'BookEditions' as Book editions succeed each other in a temporal sequence. 'BookCopies' are the copies of editions which are the actual products that are sold or exchanged; thus 'BookCopies' is modelled as a subclass of 'Products' (see Figure 3).

Although the ORM ontology does not model 'BookEditions' and 'BookCopies', BookEditions could be added to the ORM ontology (for example, Book has Editions where has is a role). Capturing 'BookCopies', however, requires an analysis of the spatio-temporal extensions of a book in order to recognise the differences between 'Books' and 'BookCopies'. The latter can only be done using the OP paradigm because of its identity analysis mechanism and philosophy that is based on extension. It is worth mentioning here that the re-engineering process follows the sequence in the BORO flowchart discussed previously and thus more objective. This process starts by selecting a concept followed by analysing its spatial and temporal dimensions in order to figure out whether it is an individual, class or property.
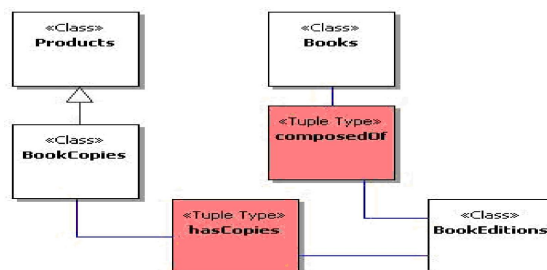

Figure 3. Re-engineering the Book Class into Book, Book Editions, and Book Copies Classes

Importantly, the re-engineering conducted so far allows us to achieve *clarity* as one of the most significant evaluation criteria of ontologies that enhances their expressiveness. Indeed, an ontology needs to successfully and objectively communicate the intended meaning of defined terms (Gruber 1995). Furthermore, the clarity and validity of the ontological expressiveness require the absence of the following deficiencies (Wand and Weber, 2002; Shanks et al., 2008):

- **Construct overload**, where two or more ontological constructs map to one modelling (i.e. grammatical) construct.
- **Construct redundancy**, where two or more modelling constructs map to one ontological construct.
- **Construct excess**, where an existing modelling construct does not map to any existing ontological construct.
- **Construct deficit**, where an existing ontological construct does not map to any existing modelling construct.

The analysis of the ontology modelled using the ORM approach reveals that it suffers from both construct overload and construct deficit. In terms of overload, the 'book' class maps to books, book editions and copies as well. In terms of deficit, book editions and copies do not map to any existing modelling construct. These deficiencies are resolved via the re-engineering process, thus we consider

that the OP ontology provides greater clarity in the resulting conceptualisation. The underlying importance of ontological clarity is that it affects human understanding of the represented phenomenon (Shanks et al. 2008).

Not only concepts, but also the properties (i.e., relationships) that exist within the ontology are examined throughout the process of re-engineering. To be more semantically precise, the re-engineering process links 'Titles', 'Authors', and 'ISBNs' to 'BookEditions' through the tuple types 'hasName', 'isWrittenBy' and 'hasIdentifier' respectively as these descriptors could change only if changes happen to editions (see Figure 4).
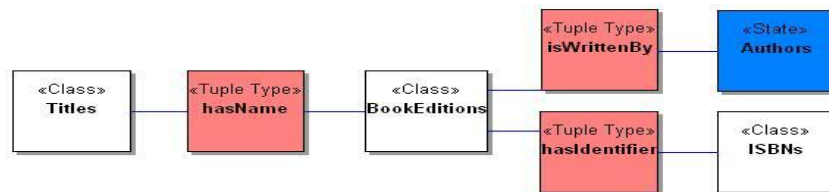

Figure 4.The Re-engineered Properties relating to Book Editions

The second set of the competency questions is related to the ability of the ontology to track changes over time. The key issue here is the extent to which the ontology can capture change happening to its objects, investigated via the following competency questions:

Q2.1 What is the price of a copy of a certain edition of a specific book at different points in time?

Q2.2 When has the price of a copy of a given edition of a specific book changed?

Q2.3 When has 'John Smith', for example, become an author?

As ORM is based on endurantism, where reality is modelled just as it is at a certain instant of time, the ORM ontology fails to answer the previous questions. To explain, let us consider the following example: My copy of 'Java how to program' was priced at £50 on 20th December 2005 and at £25 on 20th February 2009. So, the price of my copy was £50 between 20th December 2005 and 19th February 2009 and £25 from 20th February until now. With the previous analysis in mind, one can say that my copy of the book has two price states which are created by two different events (two pricing assignment events).

As the OP is perdurantist it considers the temporal dimension, thus enables capturing of changes over time. Hence, we re-engineer the ontology and include a 'PriceStates' state along with a 'PriceAssignment' event in the OP ontology. Within the OP ontology, 'PriceStates' is linked to the 'Prices' class through the 'pricedAt' Tuple Type. In turn, the 'Price' class is linked to the 'Numbers' class and the 'Currencies' class by the 'hasValue' and 'hasUnits' Tuple Types respectively. In order to capture the time at which the price assignment is happened, the 'TimeInstants' class is connected to the 'PriceAssignment' event by the 'happensAt' tuple type (see Figure 5).
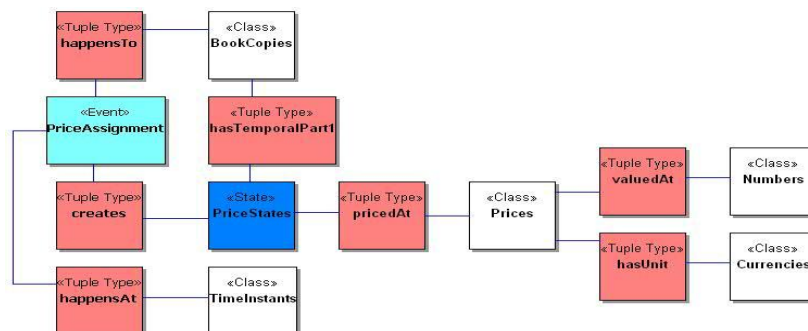

Figure 5.The Re-engineered part relating to Book Price

Such a re-engineering exercise allows us to capture more important details such as *record occurrence* and *record changes*, achieving more natural and rigorous description of the phenomenon under investigation. The OP ontology is semantically richer and more precise as it is more able to represent the real world accurately (see also Daga et al. 2005). This feature is highly important to modern information systems that are increasingly sophisticated and intelligent so as to respond to varied and more complex user requirements.
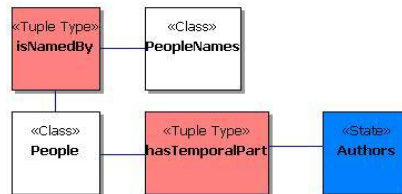

Figure 6.The Re-engineered part relating to Authors

Finally, let us now move to analyse the 'Authors' concept. In a four-dimensional paradigm, one can recognise that a person is actually an author during a specific period of their life. Being an author occupies just a stage of a person's life because they could have a different occupation, no occupation before being an author, or multiple occupations. Thus, in the OP ontology we model 'People' as a class where 'Authors' is only one state of the People class. Therefore, the 'People' class is linked to the 'Authors' state by the tuple type 'hasTemporalPart' (see Figure 6). On the other hand, people's names are obviously different objects from the people themselves who are called by these names. Therefore, in the OP ontology, the 'people' and 'PeopleNames' classes are linked by the 'isNamedBy' tuple type (see Figure 6).
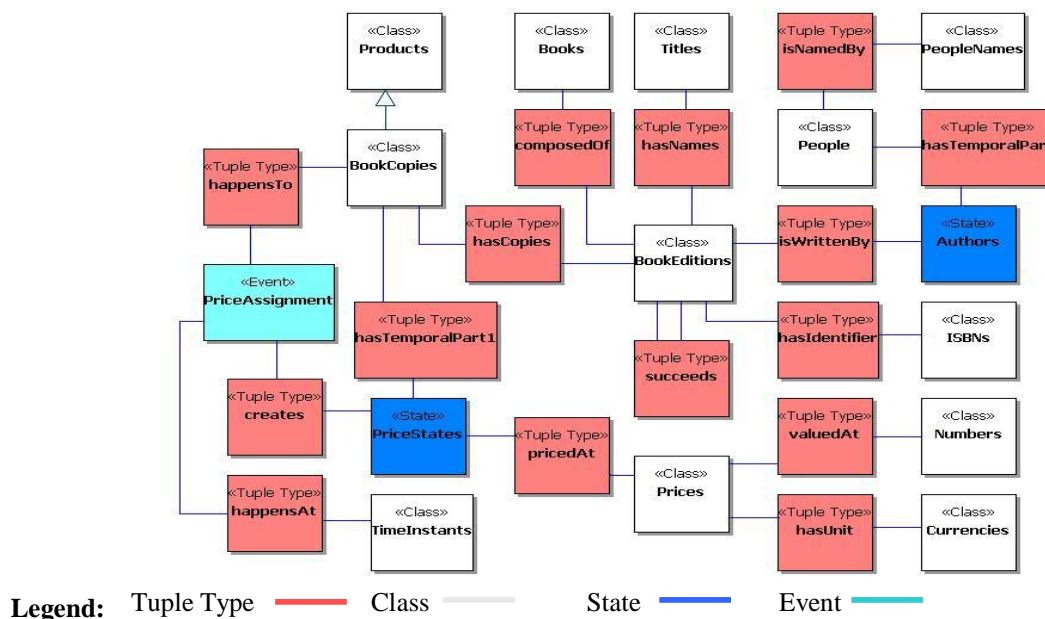

Figure 7. The OP Bookstore ontology

The re-engineered ontology is illustrated in Figure 7. Although ORM and OP have been both used in modelling ontologies, we propose that our analysis demonstrates that OP is more effective in this context. This is because, as Chandersekaran et al. (1999) argue, the following issues are important to be considered when conceptualising ontologies: (1) Real world objects and their properties change over time; (2) objects can go through different states which form temporal parts of these objects; and (3) states are created and dissolved by events. Capturing the previous important features is only possible by utilising OP due to the effective inclusion of time as a fourth dimension at the outset and not an afterthought.

5   IMPLICATIONS FOR THEORY AND PRACTICE

The comparative analysis of endurantism and perdurantism using ORM and OP as representative paradigms shows important differences between current ontological modelling approaches. This research reveals that adopting different paradigms in modelling ontologies impacts the semantic quality of the resulting ontologies. The study also highlights that the OP is more effective as it enhances the semantic representation of real world phenomena. Such enhancements may also significantly affect the quality and performance of the implemented software systems. With hindsight, the theoretical and practical implications of this study can be summarised as follows:

- **Expressiveness and faithfulness.** Expressiveness is defined as the ability of a modelling paradigm to capture all conceptually relevant domain details in a clear manner (Haplin and Bloesch 1999). This feature is very important because a highly expressive paradigm is a useful tool that enables a modeller to conceive more details than what can be captured using a modestly expressible paradigm (reflecting these details appropriately in the produced model). The conducted re-engineering exercise shows that the OP provides more expressiveness compared to the ORM as more details are picked up during the re-engineering activities. Expressiveness is a very important feature of ontologies as it enables an ontology to provide a more faithful representation of the phenomenon it abstracts. Furthermore, as we discussed in the previous section, the re-engineered OP ontology resolves the problems related to construct overload and deficit which are present in the ORM ontology, allowing more clear representation of the phenomenon under investigation.

- **Temporality of produced models.** Information systems are becoming more complex and requiring continuous tracking to the occurrences and changes of things at different time frames in order to encapsulate more intelligence. To this aim, the ontology should be able to capture things in the past, present and potential future. This requirement cannot be modelled effectively using endurantist paradigms as they just model a phenomenon as it is at a specific time from the perspective of enduring entities. A model developed based on perdurantism allows the representation of things along with their changes (states and events) in a natural and precise manner. For example, modelling `PriceStates'` as being temporal parts of `BookCopies'` enables capturing price changes in the past, present and future. Another example is the `Authors'` state of `People'`. This way of modelling reality is more accurate as people move through time from one occupation or stage to another. For instance, someone might be a student in one stage before becoming an author in a later one.

- **Extensibility to capture future business needs.** Extensibility is the ability of a model to respond to changes smoothly. In other words, a model should cater for new changes and needs without a substantial change occurring to its constructs. In a turbulent and dynamic environment, this issue has become well-known and significant in the information systems arena. Adopting a perdurantist approach, however, can produce a model that better responds to changes because of the inclusion of the temporal dimension. Any change happening to an object can be represented via states and events. To elaborate more, let us consider that a new business need has arisen requiring the ontology to capture the status (e.g. new or used) of book copies. To address this feature in the ORM ontology, a new role that could be called 'status' has to be added which might affect the unique identifier and necessitates some changes that may affect existing links to other components in the ontology-driven application. In the OP ontology, two states (new state and old state) can be added as being temporal parts of 'BookCopies'. This addition can be easily included in the existing ontology and will not affect any application using this ontology since these states are only temporal parts of an already existing object. Hence, such a significant feature leads to more flexible and reusable ontologies.

- **Objectivity.** A modelling process is arguably more objective when it provides clear guidelines for a modeller to eliminate confusion that might arise during the conceptualisation activity. Analysing the four dimensions of objects based on the BORO flowchart (see Figure 1) allows critical distinction amongst the different objects and alleviates modelling errors and bias. For example, analysing the four dimensions of 'Books' leads us to add 'BookEditions' to the OP

ontology as the four dimensions of a book are composed of the extensions of all the ‘BookEditions’ of this book.

Although the OP supports more semantically faithful representations of real world phenomena than ORM, its success is dependent on some factors such as: (1) The availability of more research on the OP; (2) the existence of supporting development tools; and (3) the ability of systems analysts and designers to understand and believe in the underlying philosophy behind such a paradigm.

6 CONCLUSIONS

Ontology is a relatively new innovation that promises to improve the design, semantic integration and utilisation of information systems. Ontologies increasingly provide the backbone of knowledge-based systems and are used to establish sharable and reusable understanding of specific domains amongst people, information systems and software agents. Notwithstanding, the ontology-related literature does not provide adequate guidance on how adopting different conceptual modelling paradigms during the analysis and design phase would impact the semantic quality of the developed ontologies and, perhaps, consequently the implemented software systems. To address this dilemma, this paper has analytically compared endurantist and perdurantist approaches using Object Role Modelling (ORM) and the Object Paradigm (OP) respectively as representatives.

The applied analysis reveals that OP (perdurantist) provides a semantically richer representation of the phenomena under investigation. The primary advantages are summarised as follows:

- *Better expressiveness*, providing clearer and more precise representation of reality based on spatial and temporal dimensions of objects.
- *Temporality*, providing the ability to capture dynamic objects showing their changes over time.
- *Better flexibility and reuse*, providing a more effective way of absorbing the changing business needs in the modern business environment.
- *Objectivity*, modelling real-life objects using a more systematic method that enjoys the merit of clearly mapping these objects into appropriate modelling constructs.

We acknowledge that the paper has some limitations in that it analyses the differences between endurantism and perdurantism by using only the ORM and OP approaches. Although the presented analysis shows some significant differences, still there is a need to delineate and validate such differences using other conceptual modelling approaches and this is the next stage of our research.

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