Providing guidance for conceptual modelling using core ontologies

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Abstract. With the purpose of better understanding the conceptual modelling process and to develop a good conceptual model, this paper presents a complete view of the modelling process. Different key points during this process are identified that have an impact on the further development of the modelling process and the final conceptual model. These key points and their impact are discussed with the purpose to integrate them into one overall, step-by-step method that serves as a guideline for the modeller during the conceptual modelling process. I present and position briefly my theory of modelling and elaborate my intended research in this field.

Keywords: Conceptual modelling process, core ontologies, ontology-driven conceptual modelling

1 Introduction

Conceptual modelling is defined as the activity of formally describing some aspects of the physical and social world around us for the purposes of understanding and communication [1]. In the context of IS development, a conceptual model represents the domain in which the system will operate independently of implementation technology and constraints [2]. It has an important role in defining, analysing and communicating the requirements of the systems to be. Outside traditional IS development, conceptual modelling also plays an increasing role in activities such as business process management, knowledge representation and enterprise design. Over the years, different conceptual modelling languages have been introduced which, in most cases, have their origin in modelling languages that were primarily used during system design. As a consequence conceptual models suffer from semantic schizophrenia "On the one hand the model represents the domain, on the other hand, it represents the implemented system, which then represents the domain" [3].

In order to make conceptual modelling languages less system oriented and more suitable for representing the real world, different researchers have turned their attention to philosophy. Specifically, they have looked to ontologies, which is the branch of philosophy dealing with modelling reality. In the philosophy domain an ontology is defined as "the study of what categories of entities there are and how they are related to one another" [4]. Within the IS domain, ontologies are used to analyse and improve existing conceptual modelling languages [5]. The approach that is followed throughout this process is strongly influenced by computers science research where an ontology is defined as a formal specification of a conceptualization [6]. My approach also tends to focus on core ontologies, which can be defined as ontologies that provide a broad view of the world, suitable for many different target domains [7]. They are used within the domain of conceptual modelling for providing real-world semantics for conceptual modelling languages. Also, they provide theoretically sound foundations and methodological guidelines for evaluating and improving the conceptual models made using these languages [8].

Consequently different conceptual modelling researchers have focused on either specifying existing ontologies or constructing new ontologies specifically for the information systems domain. Next, those ontologies were used to analyse existing conceptual modelling languages, which eventually resulted in changing the syntax. This approach is clearly visible in the work of Evermann and colleagues who have formalized the Bunge ontology using both UML and OWL [9], and have proposed a set modelling rules specific for UML class diagram modelling [10] based on the Bunge axioms. Using an existing conceptual modelling language in combination with modelling rules that have their origin in a formalized ontology is what we call *ontology-driven conceptual modelling* (ODCM). While the notion of *formal* used to imply that expressions and rules must be machine readable [7], OCDM focuses more on providing formal specifications and definitions of concepts. Or in other words, it aims at formalizing conceptual modelling languages with the aim of reducing different kind of interpretations of concepts.

Studies that have demonstrated the benefits of ODCM or that have compared the improved languages modelling with standard conceptual modelling have been scarce. Moreover in case ODCM was analysed empirically, the observed impact has been very low [11–14]. For instance the study of Soffer and Hadar [14] has shown that ontology-based rules impact the decision process of the modeller and consequently influences the model. However the observed impact was less than expected.

In the study of Soffer and Hadar [14], the complexity of the Evermann and Wand rules resulted in selecting only a subset of the rules, which automatically influences the impact of the proposed method. This brings us to one of the most important problems of ontology-driven conceptual modelling, the complexity of the formal language. This complexity has its origin in the technical approach that is currently followed, i.e. ontological axioms are translated in formal modelling rules that become part of the syntax of the language. Modellers can only successfully apply the developed rules if they fully understand the ontological background of the rules. Understanding this ontological background is complicated and time consuming. As a consequence, an increasingly problematic bottleneck in IS and system development has come about i.e. a growing demand for constant creation of formal models in specific and dynamic operational contexts, combined with a lack of people who are capable and willing to perform the modelling required [15].

In my research, I will tackle these problems by following an integrated approach that aims to fully understand the process of conceptual modelling without focusing solely on the 'end product', the conceptual model. In order to achieve this, I will examine the key steps in the development of a conceptual model. Once these key steps are identified, I will determine the different choices and decisions a modeller can take at each of these steps. Next the impact of these decisions on the development of the final conceptual model will be evaluated. Finally, these findings will be integrated into a method of conceptual modelling. This method would guide the modeller from the beginning until the end of the conceptual modelling process. From another perspective, the method could also serve as a meta-method for deriving good modelling methods for a specific modelling language. A unique aspect of this approach and method is the central role of core ontologies. They are seen as an important step for achieving a good conceptual model. Section 2 will describe in more detail the process of conceptual modelling. Here we will identify the key steps of developing a conceptual model. In section 3, I will discuss my research goals and methodology

2 The process of conceptual modelling

Hoppenbrouwers et al. [15] describe the process of conceptual modelling, based on the idea that participants in such a process are involved in a deliberate and goal-driven effort to share and reconcile representations of their personal conceptions of (parts of) the world. Here they introduce concepts such as modelling strategy and conception. A *modelling strategy* is defined as a way of proceeding in a modelling dialogue that should answer all questions related to the modelling process or the completed conceptual model. A *conception* results in the mind of the modeller. When the modeller perceives the universe, he then produces a conception of that part they deem relevant. A conception cannot be communicated and discussed with others unless it is being represented by means of using some language and medium, hence the need for conceptual modelling. For explaining my own view on the process of conceptual modelling, I borrow these concepts although I provide them with a slightly different meaning.

It is the author's belief that the quality of conceptual models can be much improved by means of a better understanding of the conceptual modelling process. Much is written about the quality of conceptual models [16]. Some criteria focus on the correctness or appropriateness of the model while others value completeness and testability. Since a conceptual model can be developed with different purposes, the quality of this conceptual model should be linked with the fulfilment of the purpose and intended use of the conceptual model. It is therefore our goal to create a method that guides the modeller with developing the conceptual model so that the final conceptual model meets its intended purpose. Thus this approach can be defined as process-oriented while being complementary to the product-oriented view.

We can translate the purpose and intended use of the conceptual model into the formulation of a modelling strategy. Once determined, this modelling strategy should accompany the modeller throughout its path of developing a conceptual model. This will retain the modeller from making any sudden changes or modifications during the modelling process, which in the end could lead to a lower quality conceptual model. Thus, we can identify the first key step of the conceptual modelling process, *determining the modelling strategy*. An example of such a strategy could be to improve the communication by means of using a limited set of concepts and relationships. Other strategies could be based upon re-engineering purposes or system analysis. Since each of these strategies have different goals, they should lead to different choices during the conceptual modelling process.

Once the modeller has identified his purpose and use for creating a conceptual model and translated this into a modelling strategy, he will then look at the aspect of the real world that needs to be modelled. Here the modeller forms a first *conception* of the model and this is also the second step in the conceptual modelling process. During the formation of a conception, the modeller identifies in his mind the main objects of the real world that need to be modelled. It is here that a first idea is formed of how the final conceptual model will or should look like. In other words, a blueprint of the conceptual model is created, where the main objects and their relationships or dependencies are identified.

The next key step in the process of developing a conceptual model is the right *choice of an ontology*. We use the words 'right choice' for a reason. Although a great deal of scientific research has been done in analysing, evaluating and improving the modelling grammars and constructs of conceptual modelling languages with ontologies [17], [18] (e.g. the development of OCDM), little research has yet been done in the choice of an ontology. In my view, ontologies can be used as a basis for a modeller's perception of viewing the real world, which as a consequence will have an impact on the actual modelling of the real world. Krogstie [19] defines perception, also called structuring principle, as a rule or assumption concerning how data should be structured. He distinguishes different modelling perspectives and uses this to classify different kind of conceptual modelling approaches. I tend to focus more on the perception of a modeller and how this perception can be altered using an ontology. Depending on the modelling strategy and the conception, the way the data is structured in the conceptual model cannot be chosen randomly. Therefore choosing the right ontology is the third step of developing a conceptual model. The ontology will bestow the modeller with a certain perception of the real world, which he can then use to correctly create a representation of the real world.

Before the modeller can start with the creation of a representation of the real world, he will first need a *conceptual modelling language* that will provide him with the right syntax and semantics. Of course, the choice of the conceptual modelling language will depend upon the modelling strategy and the preferred ontology. Since there is a vast variety of modelling languages, each developed for a certain purpose and domain, they offer a great deal of different concepts and relationships. Some research with respect to the comparison of conceptual data modelling languages has already been done. Keet [20] compared various conceptual modelling languages on their language constructs with the purpose to gain better insight in the characteristics of these conceptual modelling languages. Söderström et al. [21] compare modelling languages by means of a framework with the purposes to serve as a translating tool between the modelling languages. I however will not compare conceptual modelling languages based on the language's expressiveness but rather compare the conceptual modelling languages with both their purpose and the modeller's perception of the real world, determined by the chosen ontology.

As a final step, the conceptual model can be created to represent the aspect of the real world. The developed model should fulfil two sets of demands on quality: one related to verifiability (i.e. internal quality) of a model and the other related to validity (i.e. external quality) of a model [15]. By consequently following the modelling strategy as formulated in the beginning of the conceptual modelling process and by carefully linking the modelling mission with a certain ontology and conceptual modelling language, the developed conceptual model will result into a valid model, achieving both verification and validation.

Figure one summarizes the above-explained conceptual modelling process. In the figure, the blue rounded rectangles represent the key decision points for the modeller during the process.

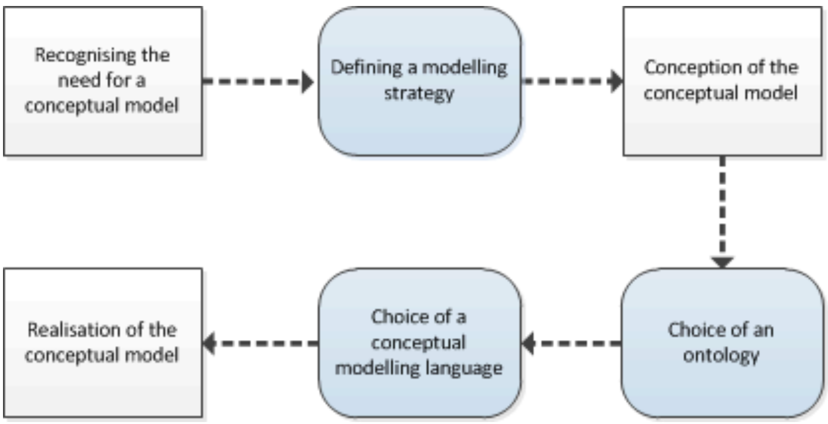

Figure 1: The process of conceptual modelling and its key decision point

3 Research Goals and methodology

Looking at the greater picture of the conceptual modelling process, my research has as main goal the development of a method on which a modeller can rely to achieve a high quality conceptual model, while also having a clear comprehension of the modelling process. This general goal can be divided into different sub goals:

- Identification and formalization of the different type of modelling strategies
- Investigation of the relationship between modelling strategies, ontologies and conceptual modelling languages
- Investigation of the impact of certain conceptual modelling process decisions on the quality of the model.
- Development and evaluation of the actual method for guiding the process of conceptual modelling.

Throughout the research project the design science methodology is followed [22]. This means that for each of my research goals, I will develop different design science artefacts. These artefacts will ultimately contribute for creating the method for guiding the conceptual modelling process. The different design science artefacts that will be developed in this project are:

- A model that explains the conceptual modelling process and identifies the important decision points.
- A theory that explains the relationship between modelling strategies, ontologies and conceptual modelling language. Additionally this theory must predict the impact of the decisions made on model quality.
- Method for guiding the process of conceptual modelling

The development of these artefacts will happen first by analysing existing literature of the conceptual modelling process in order to identify the decision points during this process. Next, different kind of ontologies and conceptual modelling languages will be analysed with the aim to select the most appropriate ontologies and modelling languages. The significance of these design artefacts and the overall method for guiding the process of conceptual modelling will be empirically tested and evaluated with a modelling experiment of novice modellers that exist out of 3rd bachelor business student from the University of Ghent.

4 Preliminary results

As mentioned above, almost no scientific research has been preformed for identifying the criteria and motivation for choosing an ontology and the effect of applying this ontology on a conceptual model. Therefore my first research aims to understand and demonstrate how the choice of an ontology matters depending on the aspect of the real world that has to be modelled. To achieve this, my approach is double fold.

My first approach aims to compare ontologies. To accomplish this, I have developed an *ontological framework* that identifies the cornerstones of an ontology, called meta-properties. Guarino et al. [23] introduce the concept of meta-properties, which represent the behavior of a property in an ontology with respect to the notions identity, unity, essence, and dependence. The result of their analysis is a cleaner taxonomy that clarifies the modeler's ontological commitments. I redefined these meta-properties in a slightly different way with the purpose not to create a taxonomy but instead to make a comparison between the fundamental subsistence of ontologies. I define meta-properties as the building blocks for the structural elements of an ontology, i.e. their concepts, relationships and the impact of changes and occurrences. I intend to use this ontological framework to analyse ontologies and ultimately select the ontologies that I will use for my research.

My second approach makes a comparison between a 3D ontology and a 4D ontology, with the purpose of identifying modelling variations that arise from using these different kind of ontologies. The modelling variations are illustrated by using 2 enterprise modelling enigmas on which both ontologies are applied. The goal of this comparison is to demonstrate that the choice of an ontology impacts the representation of real world phenomena and will eventually result in different enterprise models. I have submitted these results for the ENMO workshop at the ER 2014 conference.

Both approaches clearly demonstrated that the type of real world phenomena would be differently modelled, depending on the choice of the ontology. Determined by the meta-properties of an ontology, a rather different perception of the real world is formed. When this perception is applied on modelling real-world phenomena in a certain domain, they offer a significant and fundamental difference for conceptualising these phenomena. The developed enigmas testify to this statement.

5 Conclusion

This paper presents a complete view of the conceptual modelling process. I have identified the key points during this process that impact the further development of the conceptual modelling process and the realisation of the conceptual model. I have argued that in order to achieve a valid model; the focus should not only be on the end product i.e. the conceptual model but also specifically on the conceptual modelling process. Further research will identify the possible decisions a modeller can take in this process and understand the effect they have on the later stages of the modelling process. Once these decisions are understood, they will be integrated into a method for guiding the modeller in the conceptual modelling process.

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