The Pattern of Patterns: What is a pattern in conceptual modeling?

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Abstract

It has been proven that using structured methods to represent the domain reduces human errors in the process of creating models and also in the process of using them. Using modeling patterns is a proven structural method in this regard. A pattern is a generalizable reusable solution to a design problem. Positive effects of using patterns were demonstrated in several experimental studies and explained using theories. However, detailed knowledge about how properties of patterns lead to increased performance in writing and reading conceptual models is currently lacking. This paper proposes a theoretical framework to characterize the properties of ontology-driven conceptual model patterns. The development of such framework is the first step in investigating the effects of pattern properties and devising rules to compose patterns based on well-understood properties.

Keywords: Semantic Ontology, Visual Ontology, Conceptual Modeling Patterns, Ontology-Driven Models.

1 Introduction

In the Information Systems field, conceptual modeling is the activity that elicits and describes the knowledge about a domain that a particular information system (for that domain) needs to incorporate (1). Business ontologies and value models are particular kinds of conceptual models that are used in the early phases of information system's requirements engineering. A business ontology defines the concepts, relationships, and axioms that hold for some business domain (e.g., transactions, business processes, business policy). Having a domain model commit to a business ontology ensures precise semantics of the model elements. A value model is a conceptual model of a value web, i.e., a network of business entities (e.g., enterprises, market segments) that exchange objects of value within the frame of some ecosystem of interacting business models. As a domain model, the value model thus describes how value is created and exchanged within the domain of the value web. From such value model, requirements can be derived for how the information system of a focal actor in the value web should support and monitor the creation and exchange of value by this actor [2,3].

Value modeling, business ontology engineering, and conceptual modeling in general are important in developing or acquiring information systems as the quality of the system critically depends on the quality of the ontologies and models underlying the system [4,5]. Assuring a high level of quality in conceptual modeling is, however, challenging. The high level of domain abstraction needed to create high-quality conceptual models poses difficulties which for some people are hard to overcome [4, 6-9]. It has been shown, for instance, that a modeler's field-independency (i.e., ability to think in abstract concepts, e.g., a value embedded in the value proposition to economy passengers made by a low-cost carrier, versus the need for information on the particular frame of reference, e.g., the current price of a flight next Sunday to Ibiza from Amsterdam by Ryanair) has a strong impact on the ability to create high-quality conceptual models [10].

One way to reduce individual variety (e.g., caused by traits like field-(in)dependency) in creating conceptual models is using model patterns. It has been proven that using structured methods to represent the domain reduces human errors in the process of creating models and also in the process of using them. Using modeling patterns is a proven structural method in this regard [11]. A pattern is a generalizable reusable solution to a design problem. The main purpose of using modeling patterns is reusing previous solutions in order to help modelers to represent

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frequently recurring problems[1] in a more formalized way and also to assist in model user's understanding by making models more recognizable [11].

It has been proven that using patterns in the modeling process results in benefits for modelers [1, 12, 13] and model users [13-15]. Positive effects of using patterns were demonstrated in several experimental studies and explained using theories [12, 14]. However, detailed knowledge about how properties of patterns lead to increased performance in writing and reading conceptual models is currently lacking. Commonly, patterns are designed empirically based on (supposedly best) practice, but if they can be characterized in terms of their properties, we will be able to investigate which properties lead to certain effects under certain circumstances, which will provide knowledge to develop better patterns. If we have a property catalog of conceptual model patterns, we are able to investigate local effects of properties and by combining them we are able to assess their global effects. Knowing the specific effects of the pattern properties provides a possibility to further develop existing patterns by reconfiguring their properties.

This paper proposes a theoretical framework to characterize the properties of conceptual model patterns. The development of such framework is the first step in investigating the effects of pattern properties and devising rules to compose patterns based on well-understood properties.

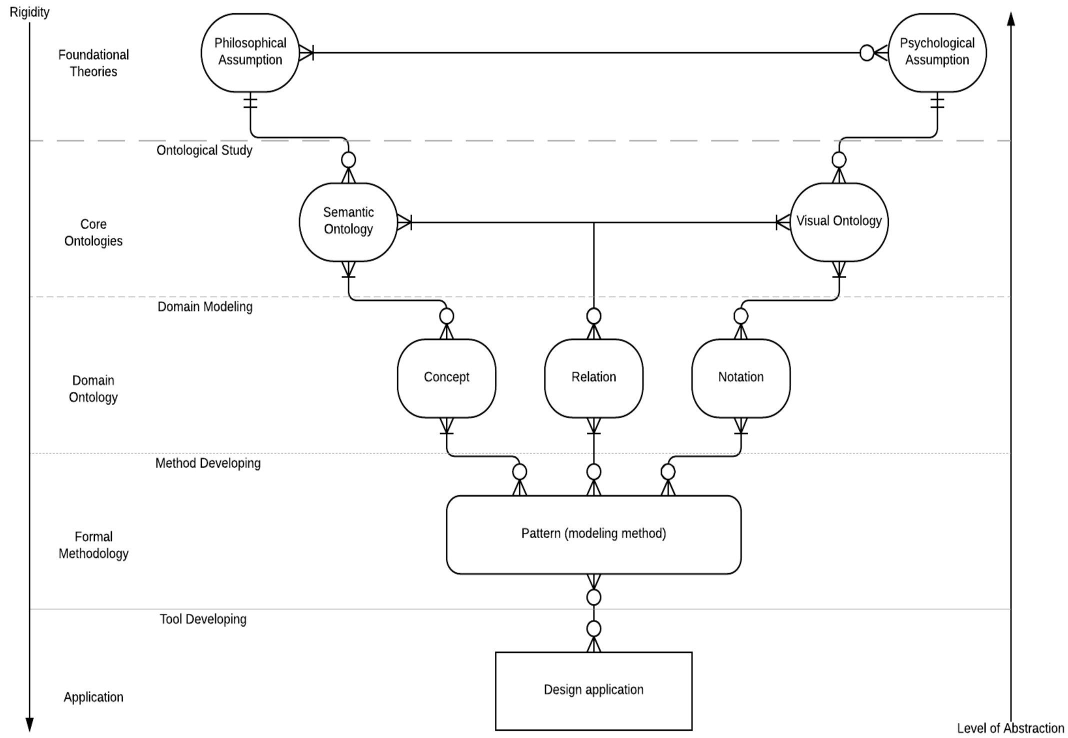


Figure 1. Theoretical framework for characterizing properties of conceptual modeling patterns

2 Discussion

The theoretical framework represents different levels of elements regarding their rigidity and the level of the abstraction. This framework represents elements from the fundamental theories underpinning the modeling patterns as the highest level of abstraction and less rigid types of elements including the final software application of the solution as lower levels of abstraction. The theoretical framework is presented in Figure 1. The next sections explain the different levels of this framework and the elements of each level.

[1] Problem in this context needs to be understood as the problem of representing some situation of reality, i.e., not the problem is represented but the representing is the problem.

2.1 Foundational theory

Any model represents things based on a singular way of looking at reality. The perspective of the modeling pattern can be defined in a school of philosophy and a school of psychology. Clarifying the philosophical assumptions which fundamentally describe the core ontology of the pattern, is a crucial and very fundamental element of the pattern [17-19]. Also, the philosophical school of the pattern accordingly specifies the psychological school of the pattern Figure 2. foundational elements of the pattern. The relation between philosophical and psychological assumptions is very important in the way of describing reality. In other words, the assumption about the aspects the humanity should be based on a unique perspective of the reality. By this clarification we objectively address all theoretical assumptions that are involved in practice (product) and it provides us a possibility to practically evaluate the performance of those abstracts and subjective theories.

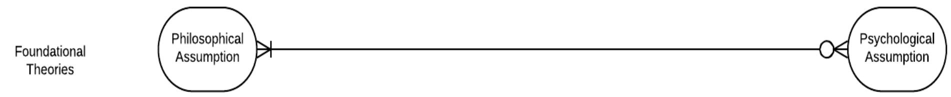


Figure 2. foundational elements of the pattern

2.2 Core Ontology:

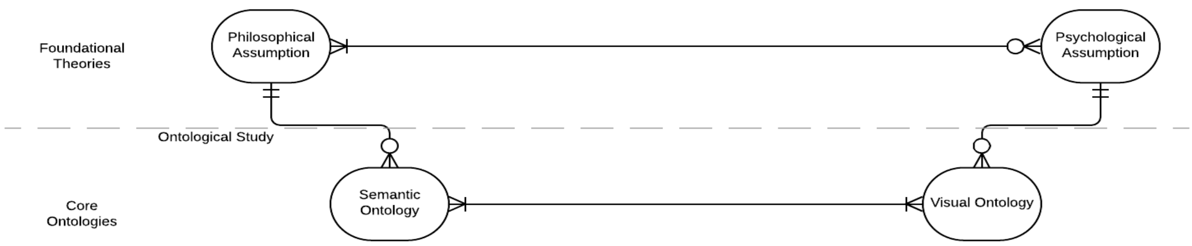
This level represents types of ontologies that are involved in the pattern Figure 3. involving elements of the pattern from basis to the core ontology level and their relationsOntology represent a taxonomy of basic concepts related to the given theoretical assumption (philosophical or psychological). Formal ontology is concerned with the systematic development of axiomatic theories describing forms, modes, and views of being of the world at different levels of abstraction and granularity. Formal ontology combines the methods of mathematical logic with principles of philosophy, but also with the methods of artificial intelligence and linguistics. At the most general level of abstraction, formal ontology is concerned with those categories that apply to every area of the world [17, 20].

Semantic ontology:

Semantic ontology defines concepts in high level of generality that provide a semantic basis for defining domain concepts. Also, it represents rules to define the relations of those concepts and the set of axioms formulated about their vocabulary. This type of ontology may differ with respect to theoretical assumptions and accordingly categories and relations. If two ontologies are based on similar philosophical assumptions, then they have similar categories and relations [20].

visual ontology:

Visual ontology defines relations and notations of defined concepts. Based on the theoretical foundation of the visual ontology, this type of ontology describes the particular way of representing concepts in the model. This ontology represents visual aspects of constructs by explaining the cognitive quality of proposed notations. Visual representations are effective as they are related to the capabilities of the powerful and highly parallel human visual system [21-23]. Regarding the structure of the designed model, a visual ontology may also provide rules for relations between concepts.
The semantic ontology and visual ontology of the pattern constitute the core ontologies of the pattern. Patterns may combine several ontologies as long as they are based on unique, non-conflicting theoretical foundations.



2.3 Domain ontology:

The domain ontology of the pattern defines specific concepts of the domain and their relations and notations based on the core ontologies of the pattern Figure 4. involving elements of the pattern from basis to the domain ontology level and their relations. Domain ontology recognizes the concepts of the domain and the relations between them and relevant notation for the specific domain [24, 25]. Any pattern can use different combinations and arrangements of elements described in the domain ontology. Any elements of the domain (concepts, relations, notations) are expressed based on one or more semantic and visual ontologies which are themselves related to a philosophical assumption and a psychological assumption. Any pattern uses a specific combination considering the type of the problem it is addressing.
A domain ontology assumed as a formal knowledge base is given by an explicit specification of a conceptualization. This specification must be articulated in a formal language, and there is a variety of formal

Figure 3. involving elements of the pattern from basis to the core ontology level and their relations

Table 1, Relation between core and domain ontology type

Core Ontology type	Domain Ontology element
Semantic	Concept: represents things in a specific domain based on the semantic ontology of the pattern.
Semantic-Visual	Relation: defined based on the semantic ontology of the pattern, although the visual ontology may modify or validate the relation based on the way of understanding (cognition) and interpreting by modelers or model users.
Visual	Notation: based on the visual ontology that concludes some visual theories such as the physics of the notation and also the structure of the design. Visual elements of a pattern are significant to make the pattern more understandable [23].

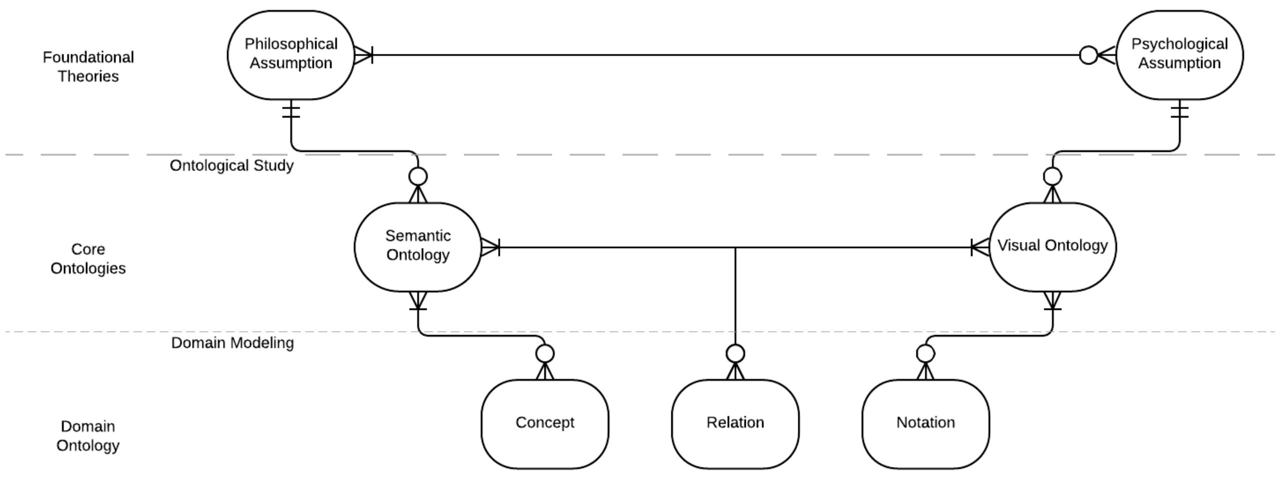


Figure 4. involving elements of the pattern from basis to the domain ontology level and their relations

2.4 Formal Methodology:

This level is less abstract and more rigid than previous levels. In this level, based on the problem in a domain, a pattern proposes appropriate concepts and their relations and notations. The pattern defines which concepts of the domain ontology are involved, how these concepts are structured to design a reusable solution that addresses the problem, and which notation should be used for the concepts and the structure of relations between the concepts. Here, at this level, the pattern gets created and gets formal Figure 5. involving elements of the pattern from basis to the formal methodology level and their relations. Patterns have a logical method to represent that combination based on the type of the task in demand.

So, any pattern uses concepts of a specific domain which are defined semantically by a semantic ontology that is itself based on a philosophical assumption [24-26]. The relation between these concepts are defined by the particular combination of two core ontologies: the semantic ontology –the same one used as for definition domain ontology concepts – and the visual ontology. The visual ontology is based on a psychological assumption that is defined in a higher level. This combination recognizes the relation between concepts based on the problem domain. Also, a pattern uses notations to design the model based on the visual ontology that is based on a psychological assumption.

The unique way of uniting mentioned elements to create a reusable solution to address a type-problem in a domain is what we define as the Pattern.

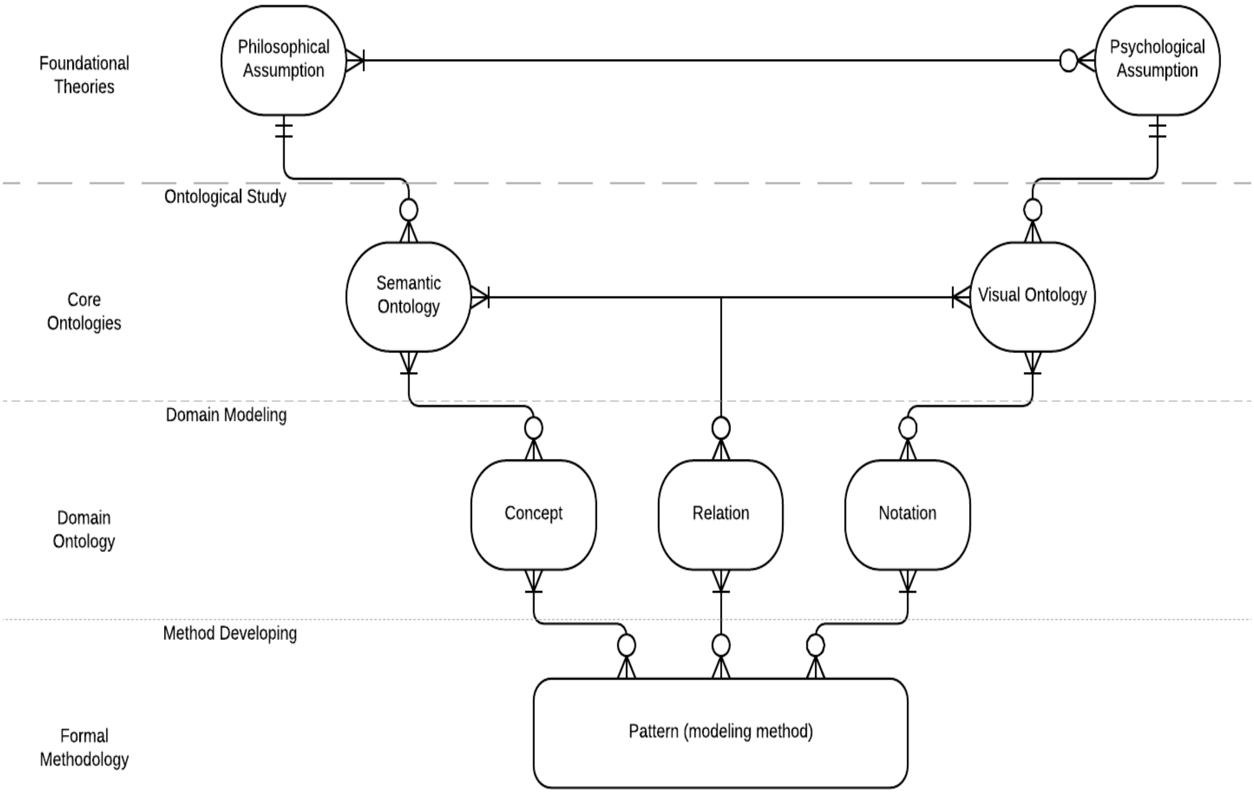


Figure 5. involving elements of the pattern from basis to the formal methodology level and their relations

2.5 Application:

The structure of patterns could be formalized and be delivered in some tools that facilitate the process of using patterns. Basically, this is the final implementation of the pattern and it has impact on the final performance of the using patterns. This part is the most rigid element of the patterns and can be evaluated by technical means only. We represent this part in order to depict the whole picture of patterns because same patterns can perform differently regarding their way of implementation Figure 6.

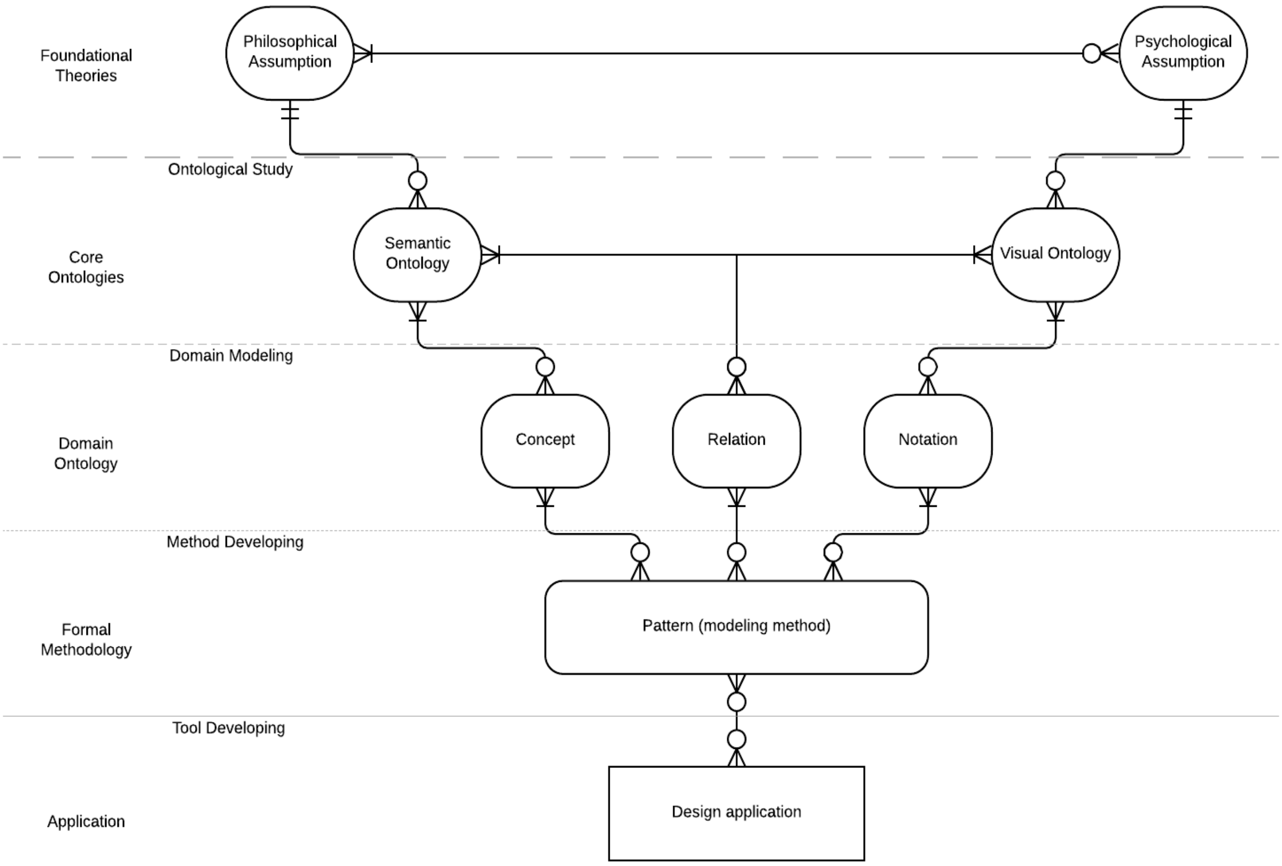


Figure 6. involving elements of the pattern from basis to the application level and their relations

3 Conclusion

The represented theoretical framework shows elements and the connection of all involved elements of the pattern. We performed an ontological approach to describe an ontology-driven method. Many attempts have been done to create ontological artifacts but still we could not integrate them properly and use the benefit of the integral reinforcement. Using unified view to creating ontology-driven models will provide us to overcome the mentioned problem. On the other hand, we can evaluate the effects of any elements explicitly and also assess the interactional effects of the involving elements on each other and the final product. The development of such framework is the first step in investigating the effects of pattern properties and devising rules to compose patterns based on well-understood properties.

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