Conceptual Modeling as an Essential Cognitive Skill

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This position statement centers on two complementary points. First, we argue that *conceptual modeling* should not be 'framed' into a 'database design only' narrative, and should be acknowledged as being a much broader discipline aimed at revealing, capturing, and studying the conceptual structures of (existing, or envisaged) domains in general. Second, we argue that more work is needed to understand the way in which we (as humans) create conceptual models, while also developing more insights on how to learn (and continuously develop) conceptual modeling skills.

We [PG24] take the perspective that humanity has long since used models to understand, redesign, communicate about, and shape, the world around us, including many different social, economic, biological, physical, and digital aspects. These models may take different shapes and forms, such as sketches, precise drawings, textual specifications, or tangible forms, all aiming to 'mimic' key properties of some original; i.e. the *domain* of the model. As such, these models are *domain models*, which we [PG21, PG24] understand to be: *a social artifact that is understood, and acknowledged, by a collective human agent to represent an abstraction of some domain for a particular cognitive purpose.*

In the context of information systems engineering, and database design in particular, an important role is played by *conceptual models*; which we [PG21, PG24] regard as a specific class of domain models. In the information systems engineering context, a conceptual model is typically used to capture the essential structures of some domain of interest (the *universe of discourse*), while avoiding the inclusion of implementation/storage details [ISO87]. The field of information systems engineering, indeed, provides a fruitful application area for conceptual modeling. At the same time, however, we suggest to avoid a 'framing' of what a conceptual model is to this application area only, and follow a more generalized understanding of the notion of *conceptual model* and its potential role. More specifically, based on [PG20, GGM19], we currently understand a *conceptual model* to be: *a domain model where the purpose of the model is dominated by the ambition to remain as-true-as-possible to the conceptualization of the domain by the collective agent, while there is an explicit mapping from the elements in the model to the latter domain conceptualization.*

We would argue that the ambition of a conceptual model, as implied by the latter definition, to remain *as-true-as-possible to the conceptualization of the domain* is not only of value in the context of information systems engineering, but other contexts as well. A conceptual model provides an explicit – human understandable – representation of a theory about the entities and their ties that are assumed to exist in a given *domain of interest*. In line with this, we observe that in many different endeavors in which we (as humans) aim to understand the workings of some domain and/or aim to express, or study, design alternatives, we actually do so in terms of (purpose and situation specific) conceptual models. This includes many examples across science and engineering at large.

Given the general, and often critical, potential role of conceptual models, we argue that it is also important to learn the skill to create conceptual models. In line with this, we argue there to be a need for more research regarding both the cognitive processes involved [WHBH13] in the creation of conceptual models, as well as strategies to teach conceptual modeling. One interesting avenue is the role of explicit verbalization if 'fact' instances as advocated by the so-called fact-based modeling approaches [HM08, HPN19]. An example would be The person with name 'Erik Proper' works for the University with name 'TU Wien'.

As posited in [HPN19], the use of such verbalizations leads to (1) models that are based of evidence (in terms of the example facts) taken from the domain of interest, (2) the models are a direct reflection of the communication about the domain of interest, (3) the models embed/use the language as used by the domain experts, enabling validation by these experts. At the same time these posited benefits are not (yet) validated in terms of empirical evidence in terms of experiments and/or observations from practice. Even more, the way in which such verbalizations may benefit the actual task – and learning – of (conceptual) modeling deserves more investigation.

Finally, one interesting avenue of potentially relevant research regarding the latter, is work done regarding the potential benefits of 'think aloud' protocols in support of cognitive processes [BR00, HVDH05, NVGB23] (including modeling processes). Here we would argue that verbalizing examples/facts from the domain to be modeled, especially when embedded in a process of verbal ('aloud') clarification and exploration, has a strong link to such 'think aloud' protocols.

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Business Informatics Group

Conceptual Modeling as an Essential Cognitive Skill

Hend*erik* A. Proper

Conceptual Modeling as an Essential Cognitive Skill

1. Conceptual database design is “just” one application area for conceptual modeling

2. We need more insights into how we (should) create conceptual models

“Conceptual”:

- a property of that what is being modeled, or
- a property of the relation between the model and that what is being modeled

Domain models

A social artifact that is

understood, and acknowledged,

by a collective human agent

to represent an abstraction

of some domain

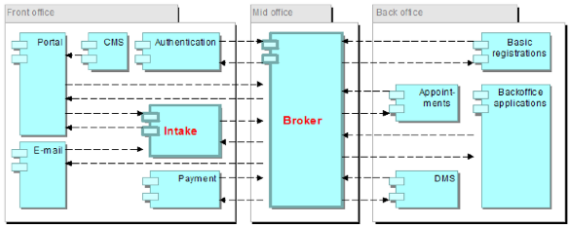
for a particular cognitive purpose

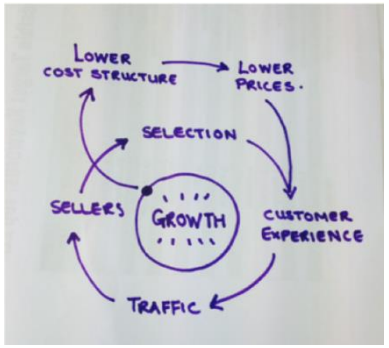
Based on Peirce, Ogden & Richards, Apostel, Stachowiak, FRISCO, …

And our own work 😇

Domain models

A social artifact that is understood, and acknowledged, by a collective human agent to represent an abstraction of some domain for a particular cognitive purpose






6. Develop Product Concept

Based on the product requirements and specifications, multiple product concepts are developed that can potentially satisfy those requirements. Brainstorming and other creativity techniques are used to generate a range of concept alternatives. These concepts are analyzed with respect to the product requirements as well as the existing technology portfolio, company capabilities, and business strategy in order to select the most promising architecture. The architecture is refined and the best aspects of other concepts are synthesized into the concept.

Tasks

1. Brainstorm and develop top-level product or system concepts to satisfy product requirements.
2. Analyze, evaluate and select a preferred product concept considering product requirements, company technology and capabilities, development risks, and business strategy.
3. Partition the system into subsystems or modules [and derive subsystem requirements
4. Brainstorm and develop subsystem concepts to satisfy lower-level requirements.
5. Analyze, evaluate and select subsystem concepts considering requirements, company technology and capabilities, development risks, and business strategy.
6. Identify need for risk-reduction development or investigation and launch effort.
7. Document the concept.

Inputs

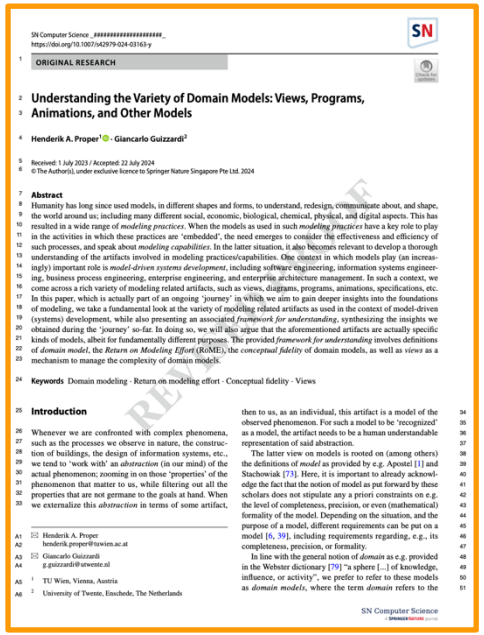
1. Product requirements document

Outputs/Deliverables

1. Product concept block diagram
2. Layout drawing
3. Concept selection matrix

Personnel Involved

Marketing
Project Manager
Design Engineers
Manufacturing Engineer
Test Engineer
Supply Management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https://doi.org/10.1007/s42979-024-03163-y

ORIGINAL RESEARCH

Understanding the Variety of Domain Models: Views, Programs, Animations, and Other Models

Henderik A. Proper[1] · Giancarlo Guizzardi[2]

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Abstract

Humanity has long since used models, in different shapes and forms, to understand, redesign, communicate about, and shape, the world around us; including many different social, economic, biological, chemical, physical, and digital aspects. This has resulted in a wide range of *modeling practices*. When the models as used in such *modeling practices* have a key role to play in the activities in which these practices are 'embedded', the need emerges to consider the effectiveness and efficiency of such processes, and speak about *modeling capabilities*. In the latter situation, it also becomes relevant to develop a thorough understanding of the artifacts involved in modeling practices/capabilities. One context in which models play (an increasingly) important role is *model-driven systems development*, including software engineering, information systems engineering, business process engineering, enterprise engineering, and enterprise architecture management. In such a context, we come across a rich variety of modeling related artifacts, such as views, diagrams, programs, animations, specifications, etc. In this paper, which is actually part of an ongoing 'journey' in which we aim to gain deeper insights into the foundations of modeling, we take a fundamental look at the variety of modeling related artifacts as used in the context of model-driven (systems) development, while also presenting an associated *framework for understanding*, synthesizing the insights we obtained during the 'journey' so-far. In doing so, we will also argue that the aforementioned artifacts are actually specific kinds of models, albeit for fundamentally different purposes. The provided *framework for understanding* involves definitions of *domain model*, the *Return on Modeling Effort* (RoME), the *conceptual fidelity* of domain models, as well as *views* as a mechanism to manage the complexity of domain models.

Keywords Domain modeling · Return on modeling effort · Conceptual fidelity · Views

Introduction

Whenever we are confronted with complex phenomena, such as the processes we observe in nature, the construction of buildings, the design of information systems, etc., we tend to 'work with' an *abstraction* (in our mind) of the actual phenomenon; zooming in on those 'properties' of the phenomenon that matter to us, while filtering out all the properties that are not germane to the goals at hand. When we externalize this *abstraction* in terms of some artifact, then to us, as an individual, this artifact is a model of the observed phenomenon. For such a model to be 'recognized' as a model, the artifact needs to be a human understandable representation of said abstraction.

The latter view on models is rooted on (among others) the definitions of *model* as provided by e.g. Apostel [1] and Stachowiak [73]. Here, it is important to already acknowledge the fact that the notion of model as put forward by these scholars does not stipulate any a priori constraints on e.g. the level of completeness, precision, or even (mathematical) formality of the model. Depending on the situation, and the purpose of a model, different requirements can be put on a model [6, 39], including requirements regarding, e.g., its completeness, precision, or formality.

In line with the general notion of *domain* as e.g. provided in the Webster dictionary [79] "a sphere [...] of knowledge, influence, or activity", we prefer to refer to these models as *domain models*, where the term *domain* refers to the

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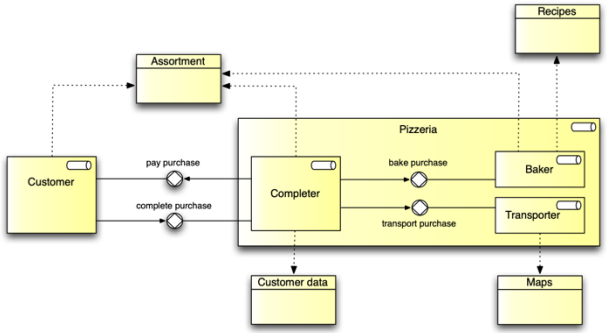

Domain models

A social artifact that is understood, and acknow
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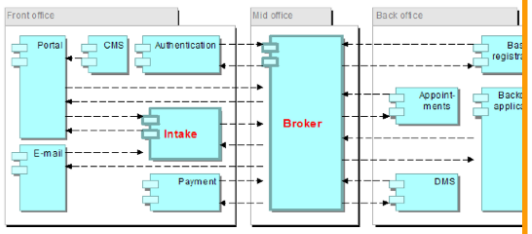
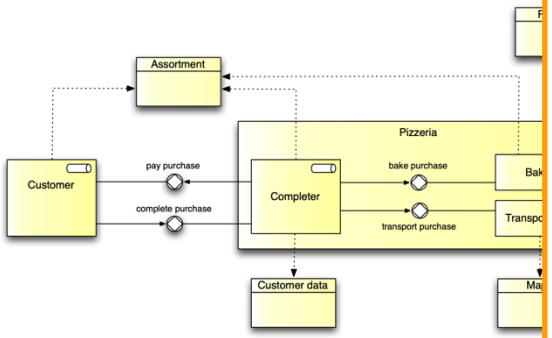
domain for a particular cognitive purpose





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ORIGINAL RESEARCH

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Conceptual (domain) model

Older roots:

M. R. Quillian. Semantic memory, Semantic Information Processing. PhD thesis, MIT, Massachusetts, 1968

as discussed in:

N. Guarino, G. Guizzardi, and J. Mylopoulos.
On the philosophical foundations of conceptual models.
Information Modelling and Knowledge Bases XXXI, 321:1, 2020

Conceptual (domain) model

A domain model, where

- the purpose of the model is dominated by the ambition to remain as-true-as-possible to the *conceptualization* of the domain by the collective agent, while
- there is an explicit mapping from the elements in the model to the latter *conceptualization*

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Conceptual fidelity

Conceptual (domain) model

A domain model, where

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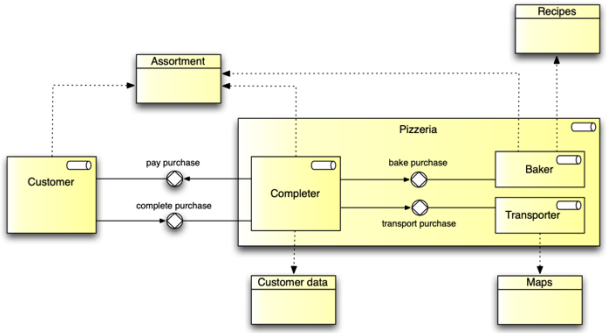
- there is an explicit mapping from the elements in the model to the latter *conceptualization*

Conceptual models have a much broader role to play in society than conceptual database design … they allow us to understand the concepts, and their relations, in any domain

Non/not-so conceptual (domain) models?



Utilization-design (domain) model

A domain model that has a representation, that is suitable for some computational or experiential purpose, which compromises the conceptual truefulness

It typically involves elements that do not pertain to the domain as such, but rather to its (designed) utilization

Could e.g. be implementation or experiental related utilization

Conceptual fidelity

How do/should we create conceptual models?

Learning grammar does not make you a great poet

So … how to model?
How to make modelers aware of their implicit (modeling) decisions?

Fact-based modeling *suggests* to start by using explicit verbalizations of “elementary facts”:

The person with name 'Erik Proper’
works for the University with name 'TU Wien'

Interesting “lead”

Think aloud protocols …

[1] Ted Boren and Judith Ramey. Thinking aloud: Reconciling theory and practice. *IEEE Transactions on Professional Communication*, 43(3):261–278, 2000.

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Not just to observe modeling processes, but specifically to make modelers more aware of their modeling acts

Conceptual Modeling as an Essential Cognitive Skill

1. Conceptual database design is “just” one application area for conceptual modeling

2. We need more insights into how we (should) create conceptual models