A Conceptual Framework for Consistency Management in Model-Based Systems Engineering

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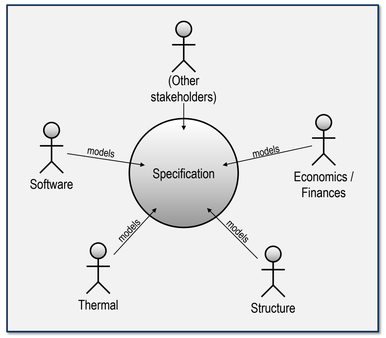
Problem Statement

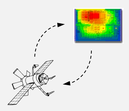
- In Model-Based Systems Engineering (MBSE) formal models are used as the means to specify systems
- Stakeholders from various domains are involved in the design and development of a complex system
- Every stakeholder has a different view on the specification (e.g. electrical, software, mechanics)



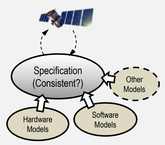
How do we make sure that the information contained within these models is consistent, i.e., how do we ensure that no contradicting information is present?

Research Challenges

To the best of knowledge of the authors consistency management in MBSE has never been studied at a fundamental level – there are, however, a few ad-hoc solutions mentioned in the literature



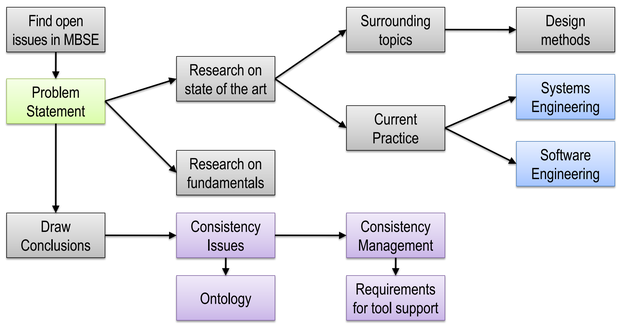
What is consistency? What consistency issues can we identify within the context of MBSE?
Being able to manage inconsistencies requires a fundamental understanding of what consistency is



To what degree can we maintain consistency? How do we determine whether or not a system specification is in a consistent state?
Find methods that aid in detecting and, ultimately, managing the different types of consistency issues

Approach

Consistency issues and management methods were identified by asking the questions: *How is design done? How are models created? How are consistency issues currently being treated?*



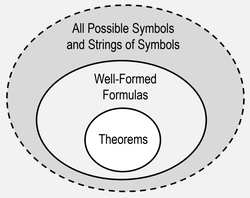
Formal Systems

Formal Languages

- Formal systems contain formal languages
- A language **L** is defined as a set of formulas:

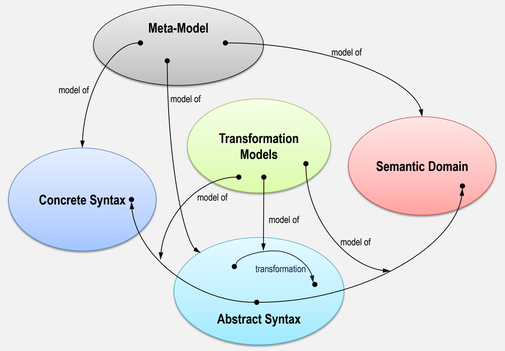
$$\mathbf{L} = \{w_1, w_2, \ldots, w_n\}$$

- The formulas or words of a language are derived using a *formal grammar* **G** that specifies axioms, inference rules and the symbols that may be used to construct words
- A formula is *well-formed* if it follows the *syntax* of the language and is therefore an element of **L**
- A formula or word is a *theorem* of **L** if it is well-formed and satisfies certain syntactical and logical conditions
- A semantic meaning may be given to every well-formed formula



Modeling Languages

- In essence the same as formal languages
- Models are words or formulas
- Meta-model is equivalent to grammar
- Differentiation between abstract (“the essence”) and concrete syntax also common in textual programming languages



Consistency in Model-Based Systems Engineering

Decision-Based Engineering Design

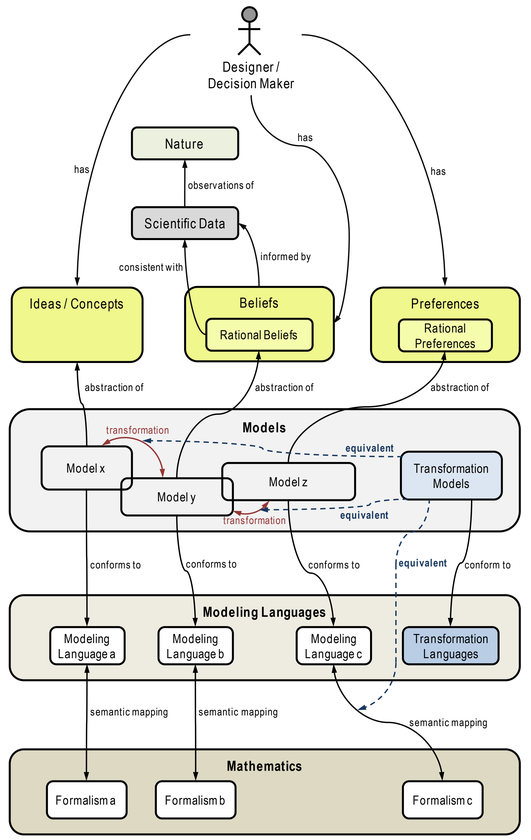
- A single decision maker has ideas (concepts), beliefs and preferences
- These ideas (concepts), beliefs and preferences are abstracted using models
  - *Beliefs* are predictions about future events and are informed by scientific data
  - *Rational beliefs* are consistent with scientific data
  - *Preferences* are rational only if they have transitive qualities and therefore show an explicit ordering

Models and Internal Consistency

- In order for models to be consistent they need to conform to modeling languages
- These modeling languages need to map to formalisms from mathematics semantically
- Transformations (based on, e.g., rules) are used to keep different models, and hence views, consistent across each other

The Dilemma of External Consistency

- Scientific data is based on observations of nature
- Nature and natural phenomena cannot be described with precision, hence checking for such *external inconsistencies* is impossible
- Raises question whether validation is possible at all



Relation to State of the Art

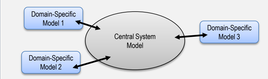
Formalization of Languages

- UML and SysML are semi-formal modeling languages - current work includes formalization of these using description logic
- Most of this work comes from software engineering

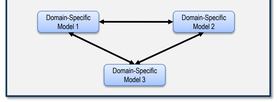
Consistency Across Views and Models

- Current research focuses on using transformations (TGG) to ensure consistency across views and models
- Two possible approaches mentioned in related literature:

Transformation from and to a central system model



Transformation across domain-specific models



Domain-Specific Modeling & Consistency

- Consistency checking across models from multiple domains requires formalism
- Current approaches utilize rules and meta-models
- Generic, domain- and application-specific concepts needed
- Illustrative example:
  - Electrical schematic shows electrical connection
  - Hence, the mechanical view must contain a physical connection (of a conductive material)

Future Work

- Develop a test case to illustrate the different kinds of consistency issues: camera payload of a picosatellite
- Implement consistency checking methods in tools

At what point in the design process should a consistency check be performed? What part of the system specification should be examined?

Academic Collaborators

Georgia Institute of Technology
Model-Based Systems Engineering Center

Technische Universität München
Institute of Astronautics

KTH Royal Institute of Technology
Department of Machine Design

Publications

Herzig, S. J. I., Qamar, A., Paredis, C. J. J., Reichwein, A. (2011). *A Conceptual Framework for Consistency Management in Model-Based Systems Engineering.* ASME 2011 – International Design Engineering Technical Conferences & Computers and Information in Engineering Conference – IDETC/CIE 2011. Washington, DC, USA, August 2011. *(under review)*