Semantics for (Meta) Models

– Proposal for: Praxis der Forschung –

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When dealing with models in model-driven scenarios, their syntax (i.e. deciding if a diagram constitutes a well-defined model) is a well-understood concept and usually handled very elegantly and effectively using meta-modelling frameworks.

The semantics of models (i.e., what precise requirements or constraints a model describes), on the other hand, is in many cases less obviously obtainable. Oftentimes, it is implicitly defined by the implementation of a model-based analysis (program) that computes, for example, a metric, property check, or analyses a quality property, for one particular given instance of the meta-model.

Especially when composing model-based analyses to allow for more comprehensive analysis results the semantics of the single analysis techniques as well as the composed semantics must be well understood to answer fundamental questions on semantical correctness, validity, semantics and property preservation, and proper executability of composed analysis techniques.

Another promising approach to define the semantics is to define a mapping from instances of the meta model into another existing language which already has a formally defined semantics. The benefits of such a transition include that several analysis tools can process this input (like different model checkers with a common input language and a common semantic understanding) and that this procedure opens the path to more formal analyses that can operate on artifacts with a formally defined semantics (rather than defined by implementation). This approach however requires the existence of joint formalisms to integrate (transform to) the different meta-models, or at least a well-founded confidence that a joint formalism can be constructed.

Research Goal 1: Survey and Classification of "model to formal" encodings

A systematic literature review should be conducted to collect, classify and describe relevant translations from modelling artefacts (or rather from the meta-model) into artifacts used in analyses (like petri nets, formal automata, code, Kripke structures, state transistion systems).

Understanding the decomposition and composition of semantics is a prerequisite to defining compositional analysis techniques. This systematic literature review should reveal the state of the art with respect to composition operators for metamodel as well as composition operators for analysis techniques and give an overview of existing approaches to ensure semantics preservation in model-based analyses. Based on the survey results concepts and guidelines for the semantics-aware decomposition, composition, and extension of modelling languages and analysis techniques should be defined an evaluated based on case studies.

Research Goal 2: Guidelines for Model Encodings

With the survey at hand, a procedure could be formulated that gives methodologists a guideline when it comes to providing semantics via a transformation into an existing formalism. What are the options? Which particular way is followed best under what circumstances? What should be considered?

We consider that this procedure contributes to a much needed bridge between model-driven and formal software engineering. It is undoubted that each meta model can somehow be enriched with a formal semantics by a translation into some formalism. But rather than designing such a translation independently and in an ad-hoc fashion for every single meta model, an understanding of how this should be done systematically would advance the field considerably.

Research Goal 3: Model Slicing

Program slicing is a valuable technique for simplifying software systems by isolating specific semantic aspects while preserving program behavior. Formally, it constructs the most concise program that upholds the semantics of the original program according to a defined slicing criterion. This concept has been extended to models, enabling the creation of sub-models that can be processed more efficiently. In this context, how can the transformational semantics of models studied in the first part of the project be used to provide new slicing criteria for model slicing? What slicing techniques can be derived for semantics-enriched models? We are particularly interested in deriving slicing techniques for semantics-enriched models, with a particular emphasis on consistency-preserving slicing. In consistency-preserving slicing, the slicing criterion is determined from the semantics of another model. Indeed, models typically describe interconnected aspects of a system, necessitating a collection of models to represent the system thoroughly. Once each model is endowed with appropriate semantics, system analysis often requires the examination of cross-model properties. Simplifying a model based on its overlap with another model could, therefore, simplify the analysis of interconnected models. Thus, the third research goal should investigate how integrating transformational semantics and slicing techniques can streamline the processing of complex systems.