A systematic and practical method for selecting systems engineering tools

The complexity of many types of systems has grown considerably over the last decades. Using appropriate systems engineering tools therefore becomes increasingly important. Starting the tool selection process can be intimidating because organizations often only have a vague idea about what they need. The tremendous number of available tools makes it difficult to get an overview and identify the best choice. Selecting wrong tools due to inappropriate analysis can have severe impact on the success of the company. This paper presents a systematic method for selecting systems engineering tools based on thorough analyses of the actual needs and the available tools. Grouping needs into categories, allow us to obtain a comprehensive set of requirements for the tools. The entire model-based systems engineering discipline was categorized for a modeling tool case to enable development of a tool specification. Correlating requirements and tool capabilities, enables us to identify the best tool for singletool scenarios or the best set of tools for multi-tool scenarios. In both scenarios, we use gap analysis to prevent selection of infeasible tools. We used the method to select a traceability tool that has been in successful operation since 2013 at GN Hearing. We further utilized the method to select a set of tools that we used on pilot cases at GN Hearing for modeling, simulating and formally verifying embedded systems.

Test-Driven, Model-Based Systems Engineering.

Hearing systems have evolved over many years from simple mechanical devices (horns) to electronic units consisting of microphones, amplifiers, analog filters, loudspeakers, batteries, etc. Digital signal processors replaced analog filters to provide better performance end new features. Central processors were added to provide many functions for monitoring and controlling other parts of the devices. Hearing systems have thus evolved into complex embedded system. Radio systems were added to allow hearing aids to communicate with accessories, auxiliary equipment, third-party products, etc.
Many new features are enabled by such radio communication. Monitoring and controlling hearing aids from remote control devices or smart phones have been incorporated into several products. Direct audio streaming between hearing aids and dedicated streaming devices or smart phones is possible with some products. Also emerging are advanced features that are based on interactions with internet services, clouds, etc. Hearing systems are thus evolving into large and complex smart systems. Designing complex embedded systems or large smart systems are notoriously difficult. Many systems are still developed using document-based methods, where requirements and proposed architecture are described textually with the addition of a few figures and tables. Such documents cannot be subjected to testing, so it is impossible to predict the functionality and performance or even feasibility of the intended systems. Replacing documents with models have several advantages. Models can be simulated and analyzed such that functionality and performance can be predicted before any parts have been built. Potential flaws in the specification can therefore be corrected in early phases, which may reduce development effort and costs. This thesis concerns methods for identifying, selecting and implementing tools for various aspects of model-based systems engineering. A comprehensive method was proposed that include several novel steps such as techniques for analyzing the gap between requirements and tool capabilities. The method was verified with good results in two case studies for selection of a traceability tool (single-tool scenario) and a set of modeling tools (multi-tool scenarios). Models must be subjected to testing to allow engineers to predict functionality and performance of systems. Test-first strategies are known to produce good results in software development. This thesis concerns methods for test-driven modeling of hearing systems. A method is proposed for test-driven modeling of embedded systems of medium complexity. It utilizes formal model checking to guarantee functionality and performance. Test-driven design space exploration is enabled by using statistical model checking to obtain estimates that are verified formally at the final stages of the method. The method was applied with good results to a case study, where two solutions to a design problem were developed and verified. Feasible ranges for critical parameters were identified. Both solution conformed to all requirements. Smart systems are typically too large and complex to be verified by formal model checking, and the research showed that statistical model checking in its current form cannot be used for verifying such systems. A new method is therefore proposed for test-driven modeling of smart systems. The method uses formal verification of basic interactions. Simulations are used for verifying the overall system. To predict performance for scenarios that are too large to be simulated, the method uses mathematical forecasting based on simulating series of smaller scenarios, fitting simulation results to estimator functions, and extrapolating beyond the simulated data set. Mathematical forecasting allowed us to predict the performance of system scenarios that were much too large to be simulated. Such performance estimates may be somewhat imprecise but are nevertheless valuable because they provide answers that cannot be obtained otherwise. The research has thus proposed and verified methods for selecting modeling tools and for test-driven systems modeling for the benefit of GN Hearing and other organizations involved in development of complex embedded systems of large smart systems.
develop various scenarios for a cloud-enabled medical system. Our approach provides a versatile method that may be adapted and improved for future development of very large and complex smart systems in various domains.

**Test-driven modeling of embedded systems**

To benefit maximally from model-based systems engineering (MBSE) trustworthy high quality models are required. From the software disciplines it is known that test-driven development (TDD) can significantly increase the quality of the products. Using a test-driven approach with MBSE may have a similar positive effect on the quality of the system models and the resulting products and may therefore be desirable. To define a test-driven model-based systems engineering (TD-MBSE) approach, we must define this approach for numerous sub disciplines such as modeling of requirements, use cases, scenarios, behavior, architecture, etc. In this paper we present a method that utilizes the formalism of timed automats with formal and statistical model checking techniques to apply TD-MBSE to the modeling of system architecture and behavior. The results obtained from applying it to an industrial case suggest that our method provides a sound foundation for rapid development of high quality system models.

**Projects:**

**Test-driven model-based development of complex embedded systems**

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Period: 01/08/2013 → 16/08/2017
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