QUANTITATIVE SYSTEM PROPERTIES
IN MODEL-DRIVEN-DESIGN
OF EMBEDDED SYSTEMS

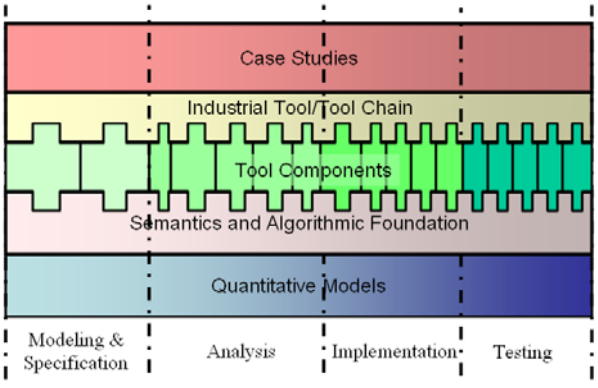
Quasimodo

Key Innovation

Embedded systems are a modern technology that is rapidly changing society as we know it. Intelligence, in the form of software and hardware, is introduced into all kinds of products and objects with the objective of enhancing their functionality. Existing promising model-driven tools for development of real-time embedded systems are rather sophisticated in handling functional requirements but their treatment of quantitative properties is still very limited. Quasimodo aims at developing theory, methods and tools for model-driven system design that can increase system development productivity of complex embedded systems while achieving predictable system safety, real-time, performance and dependability properties.

Technical approach

In MDD design decisions, analysis, code-generation, testing, etc. are always based upon design models. To focus on aspects such as performance, timeliness, and efficient resource-usage, which are central to embedded systems, the models and their semantics must be extended to include quantitative information such as information about timing, cost, data, stochastics and hybrid phenomena. Algorithmic methods will be developed for analysis of functional correctness and quantitative properties. The analysis methods include data-structures for symbolic exploration of the behaviour of models, abstraction and compositionality principles for relating design models and help to control the size and complexity of the models, exploitation of approximate analysis techniques for partial analysis of very complex models and, orthogonally, optimal utilisation of the given computing platform on which the algorithms are implemented.



In the implementation step, executable code running on given physical devices has to be provided. Unlike the theoretical frame work, real CPUs are subject to hard limitations in terms of frequency and memory-size. Thus, how to guarantee that properties established by a given model are also valid of its

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Community contribution to the project

1.995.000€... Euro

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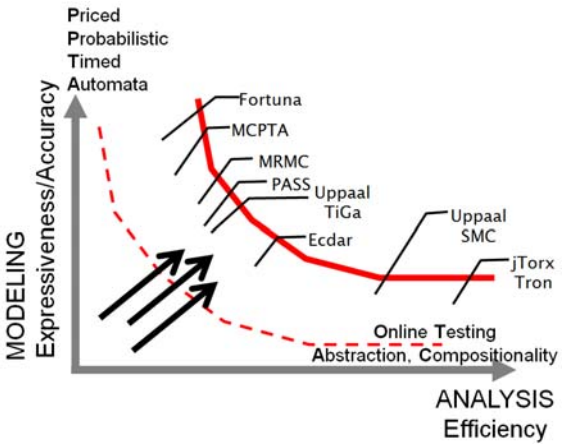
1 January 2008

Duration

40 months

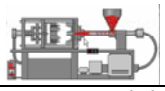
implementation is a major challenge. Current industrial testing practise is often manual without effective automation and is consequently rather error prone and costly: it is estimated that 30-70% of the total development cost is related to testing. Model-based testing is a novel approach to testing with high potential of improving cost and efficiency. We extend the model-based testing technology to the setting of quantitative models.



Quasimodo has dramatically advanced analysis techniques for quantitative models. The techniques may be classified according to the richness of the aspects captured by the model/verification property, and by whether exact or approximate analysis techniques are being used. Quasimodo has advanced state of the art both in the richness and performance of the analysis techniques, using both exact and approximate techniques, by pushing the frontier of analyzable problems. Nearly all of the techniques have been implemented in prototype tool components, and several in mature tools.

Demonstration and Use

Quasimodo has applied and evaluated its techniques and tools on a large set of industrial case studies. Important and impressive results have been achieved, and selected results are summarized below. Quasimodo is in the process of writing a handbook targeted towards industrial practitioners explaining from first principle how the proposed techniques can address quantitative properties in modelling, analysis, synthesis and testing of embedded systems.

Case study	Problems	Results
Hydraulic pump Ctrl. 	– Synthesis of Controllers – Software Testing	– Application of our tool suite for automated controller synthesis resulted in a safe controller with 33% improved energy efficiency – Model-based testing revealed significant defects in an existing implementation.
MAC protocols in Wireless Sensor Networks 	– Timing analysis – Performance analysis – Software Testing	– Real-time model-checking identified a design-flaw in the studied MAC protocol (demonstrated that clocks may become de-synchronized in certain topologies). – Message collision rates and effectiveness of collision detection were analysed using stochastic models and discrete event simulation – Real-time model-based testing identified unexpected behaviour during start-up and re-synchronization
Satellite attitude and control software 	– Schedulability Analysis	– A framework was developed for model-based schedulability analysis that may be more optimistic that classical response time analysis

Scientific, Economic and societal Impact

By enabling early and automated analysis, design, and test of quantitative properties in embedded systems, the results of Quasimodo will increase the competitiveness of European embedded systems industry and will help establish Europe as a leader in design of complex embedded systems. This objective will be reached by both advancing the state-of-the-art of models, tools and methods for quantitative design, together with knowledge transfer to European industries.

Project partners	Country
Aalborg University	DK
Embedded Systems Institute	NL
RWTH Aachen University	DE
Universität des Saarlandes	DE
Université Libre de Bruxelles	BE
ENS-Cachan/CNRS	FR
Terma A/S	DK
Hydac Gmbh	DE
Chess Beheer B.V	NL