VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

Kansliets noteringar Kod	Dnr
2014-45212-115235-57	2014-5057

2014
Project Research Grant

Area of science
Natural and Engineering Sciences

Announced grants
Research grants NT April 9, 2014

Total amount for which applied (kSEK)

2015	2016	2017	2018	2019
1732	1793	1016	1034	1054

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Administrating Organisation
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DESCRIPTIVE DATA

Project title, Swedish (max 200 char)
Effektiv modell-baserad testning av parallella system

Project title, English (max 200 char)
Effective model-based testing of concurrent systems

Abstract (max 1500 char)
Testing has become a major bottleneck in embedded software development. Embedded software is often tested too late, too little, and in an ad-hoc manner. Model-Based Testing (MBT) is a promising solution that offers a structured and rigorous approach to testing.

Three issues hamper application of MBT: First, abstract models of interface behavior are rarely available. Second, even when models are available, selecting and generating concrete test-cases (including test-data selection), with sufficient coverage is far from trivial. Third, current MBT practices do not scale up to distributed and concurrent systems.

We address these issues by leveraging and integrating several bodies of knowledge, namely, domain-specific languages, operational semantics, MBT, symbolic execution, concolic testing, compositional reduction and verification techniques, testability guidelines, and test selection and adequacy criteria.

First, we propose a unified semantic framework that consolidates the effort in applying MBT to domain-specific languages. We enrich the semantic models automatically with data-selection information from the test model and the implementation. The novel hybrid (model- and implementation-based) coverage criteria are used to guarantee efficient selection of data parameters and behavioral traces to tackle concurrent systems. Finally, we exploit compositional model reduction approaches as well as testability guidelines to address scalability issues.

Kod
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Abstract language
English

Keywords

Review panel
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Project also includes other research area

Classification codes (SCB) in order of priority
10201, 10205,

Aspects

Continuation grant
Application concerns: New grant
Registration Number:

Application is also submitted to

similar to:

identical to:

ANIMAL STUDIES

Animal studies
No animal experiments

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ENCLOSED APPENDICES

A, B, C, N, S

APPLIED FUNDING: THIS APPLICATION

Funding period (planned start and end date)

2015-01-01 -- 2019-12-31

Staff/ salaries (kSEK)

Main applicant	% of full time in the project	2015	2016	2017	2018	2019
Mousavi (salary + 47% overhead)	20	293	301	310	321	329
Other staff						
Ph.D. student (salary + 47% overhead)	75	476	497	540	572	594
Postdoctoral researcher (salary + 47% overhead)	80	731	753			
Total, salaries (kSEK):		1500	1551	850	893	923

Other project related costs (kSEK)	2015	2016	2017	2018	2019
Extended visits for Ph.D. student		35	35	35	
Extended visits for postdoc	35	35			
Open access journals publication costs	10	10	10	10	10
Conference and workshop visits	30	30	30	30	30
Collaborators travel costs	25		25		25
Overhead costs (47% of salary costs)					
Office costs (Ph.D. and postdoc)	132	132	66	66	66
Total, other costs (kSEK):	232	242	166	141	131

Total amount for which applied (kSEK)

2015	2016	2017	2018	2019
1732	1793	1016	1034	1054

ALL FUNDING

Other VR-projects (granted and applied) by the applicant and co-workers, if applic. (kSEK)

Funds received by the applicant from other funding sources, incl ALF-grant (kSEK)

POPULAR SCIENCE DESCRIPTION

Popularscience heading and description (max 4500 char)

Testning har blivit en stor flaskhals inom inbäddad mjukvaruutveckling. Inbäddad programvara testas ofta för sent, för lite, och på ett ostrukturerat sätt. Modellbaserad testning är en lovande lösning som erbjuder en rigorös och strukturerad metod fór testning. I detta projekt behandlar vi flera frågor som hämmar utbredd tillämpning av modellbaserad testning i nuvarande praxis för utveckling av inbyggda system. Med hjälp av domänspecifika språk gör vi det möjligt för domänexperter att tillhandahålla de modeller som behövs för testning. Genom att därefter använda automatiskt genererade sammanfattningar av systemet, och mekaniserade transformationer, omvandlar vi de domänspecifika modellerna till effektiva konkreta testsviter.

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Title of research programme
Effective model-based testing of concurrent systems

Appendix A

Research programme

Research Program (Appendix A)

Purpose and aims

Testing and debugging account for more than half of the software development costs and are becoming serious bottlenecks in the software development process [Myers+13]. The problem is intensified in embedded systems due to the tight coupling between software and its hardware platform and the increasing level of concurrency and distribution; hence, embedded software is often tested too late and too little and in an ad-hoc and unstructured manner. Concurrency faults are particularly difficult to find and are extremely difficult to reproduce. Due to their critical application areas, faults in embedded systems may turn into failures with very severe consequences; see [Sandler+10] for several instances of failures in the healthcare domain.

A promising solution to testing issues lies in Model-Based Testing (MBT) [Broy+05,Tretmans08], which provides a structured approach to testing from high-level behavioral models. Our vision is that MBT is instrumental in mechanizing the test process. Embedded software is particularly suitable for MBT, because behavioral and reactive aspects, emphasized by MBT, play a prominent role in its correctness.

Three issues hamper the application of MBT: First, abstract models of interface behavior are rarely available. Second, even when models are available, selecting and generating concrete test-cases (including test-data selection), with sufficient coverage is far from trivial. Third, current MBT practices do not scale up to distributed and concurrent systems.

We overcome these major obstacles by exploiting structural information from the specification and the system under test in order to enrich the initial test models, to structure the test suite in a compositional manner and to effectively choose data and increase model and implementation coverage.

The general objectives of our research agenda are summarized below:

- Using *domain-specific abstractions* as starting points for test models,
- *Augmenting behavioral models* with structural information from the *implementation* domain in order to generate effective concrete test-cases,
- Devising effective mechanized *test-data-selection* criteria, by integrating *model- and implementation-based* information as well as redefining *test-adequacy* in this hybrid setting,
- Enabling *compositional testing* for concurrent systems in order to manage complexity,
- Devising concrete *design for testability* guidelines for a semantic model of specification languages and translating them to examples of domain-specific languages.

To our knowledge, no solution integrating the above-mentioned aspects has been provided hitherto; once provided, such a solution will remove the above-mentioned three obstacles in applying MBT. The proposed research is very timely, witnessed by the constant developments in the proposed areas and recent partial solutions (see e.g., [Peleska+13, Saarkivi+12]). The principle investigator is in constant interaction with key figures in the field and maintains collaboration with several of them (e.g., the co-proposers of this proposal and the group leaders of the aforementioned recent results).

Survey of the field

The proposed research leverages and integrates prior knowledge from the following fields:

- **Formal Conformance Testing:** starting from a uniform semantic domain such as a symbolic labeled transition system (SLTS) [Frantzen+06] or extended finite state machine (EFSM) (e.g., [Petrenko+04]), automatic test-case generation algorithms can be applied to derive test-suites to perform conformance testing. There are a rich body of theoretical research and numerous tools for formal conformance testing; see [Broy+05,Dorofeeva+10,Tretmans08]. This provides a solid basis for our research.

- **Symbolic Execution and Concolic Testing:** Symbolic execution has been successfully applied to test and verify computer (particularly software) systems in the past ten years [Williams+05,Godefroid+05,Sen+05]. To apply symbolic execution in software testing, one usually starts by running the system under test (symbolically or concretely with random seed values) and following the execution trace until reaching decision points. Conditions at decision points are accumulated along the execution and by using constraint solvers (such as powerful satisfiability-modulo-theory-solvers), the obtained conditions are turned into concrete valuations for parameters. Hence, new concrete test cases are obtained, leading to maximum coverage of the code. This technique is often called "*concolic* (a combination of *conc*rete and symb*olic* techniques in) *testing*".

- **(De-)Compositional Testing:** Semantic models for concurrent systems result in hugely complex structures, and exploiting compositionality to manage this complexity is inevitable. There are a number of attempts in bringing compositionality to the domain of conformance testing [Bijl+03, Villa+12, Noroozi+13-1]. Particularly, in relation to concurrency faults, we need to exploit the compositional nature of concurrent models in order to efficiently traverse their state-space and focus on the most vulnerable scenarios. In this regard, techniques from model-checking, (e.g., partial-order and symmetry reduction [Jaghoori+12]) need to be adapted into this domain (see [Saarkivi+12] for a recent attempt).

- **Test (data) selection techniques:** Functional testing techniques were developed for selecting representatives from the large input domain of parameters (e.g., equivalence-class based and pairwise testing and category-partition method [Ammann+08, Chapter4]). Further research has been performed to create a firm fundamental ground for such techniques, leading to notions such as regularity and uniformity [Rapps+85,Gaudel+10]. Moreover, there are recent attempts to define model-based test selection criteria to steer the test-case generation process [Feijs+02, Volpato+13,Weiglhofer+09]; integrating such criteria with white-box test-selection criteria leads to an efficient testing process. For some initial results, see [Peleska+13], which relies on some assumptions about the implementation without providing a means to verify these assumptions.

- **Testability criteria:** Generating effectively covering test-suites for concurrent systems, let alone their exhaustive verification, is extremely challenging. A major point of inspiration to overcome this challenge is design for testability criteria, originally developed for hardware systems [Willimas+83] and later exploited in the domain of software [Voas+95,Harman+08]. This line of research is exploited in this project for 2 purposes: first, to find those executions that are less likely to be exercised or deviate significantly from the models and second, to come up with guidelines for modeling and implementation that lead to more effective model-based testing. One area, on which we particularly focus is testability for concurrency, based on our earlier results [Noroozi+14-1.Noroozi+14-2]. There is a link between testability criteria and compositionality in testing, as, e.g., indicated in [Voas+95]; namely, exploiting compositionally structured models and implementations and aligning these structures can lead to more effectively testable systems.

- **Operational Semantics**: Using a standard operational semantic format [Mosses04, Mousavi+07, PlanComps, Rosu+10] for test models (specified in a domain specific language – DSL) allows us to focus on a uniform meta-theory for test-case generation, as well as, automatic reflection of testability guidelines to the syntax of the DSL at hand. We experimented with testability guidelines in the semantic domain in our earlier research [Noroozi+13-2] and using a unified framework, allows for a unified theory of testability that can be instantiated mechanically for different DSLs.

Project Description

Background and Motivation

The present research builds upon the history of research (also contributed by the principle investigator and his collaborators) on applying model-based testing to embedded systems. In our past experience [Asaadi+11,Vishal+12,Keshishzadeh+13], we have observed that in industrial practice, appropriate symbolic models of interface behavior are often non-existent. Moreover, even when such models are purported, selecting and generating concrete test-cases (including test-data selection), which efficiently cover a particular implementation, are non-trivial problems. The common practice to solve this problem is to either design sophisticated test-models with detailed data specifications, or to implement ad-hoc adapters, which augment abstract messages from MBT engines with (mostly randomly generated) test data, and follow the appropriate communication protocol. Despite the substantial effort required for both approaches, neither provides any guarantee for efficient coverage, with respect to the test model or the implementation under test.

Theories

The proposed research agenda addresses the above-mentioned issues and is realized by leveraging, incorporating and integrating different bodies of knowledge from the following inter-related areas: DSLs, operational semantics, formal conformance testing, symbolic execution and concolic testing, (de)compositional testing (also test in context), test selection and coverage criteria, testability guidelines. Integration of these disciplines will lead to a unique and novel practical framework for conformance testing which starts from test models specified in DSLs and ends up with efficient and effective test-suites. There have been a number of attempts to combine some of the above-mentioned theories, but to our knowledge, no MBT framework has integrated them all. In the next section, we describe how we envisage the integration of these bodies of knowledge into a seamless MBT framework for DSLs.

Methods

Lack of appropriate test model and the learning curve of making abstract models for testers is an obstacle in the broad application of MBT. A solution that has been proven successful is using DSLs as test models [Keshishzadeh+13]. DSLs use, as abstractions, precisely those domain concepts that are deemed essential by the domain experts. To keep our project focused, we provide a unified and compositional *semantic domain* for DSLs, which is designed for testing. This compositional and symbolic domain will give us an abstract foundation for using and extending the theories of *conformance testing* and *testability*; such theories can then be instantiated uniformly for many different DSLs. Our prior experience with semantics of DSLs and specification languages provides a starting point in defining the unifying framework. Another point of inspiration comes from the meta-theory of operational semantics [Mousavi07, PlanComps, Rosu+10].

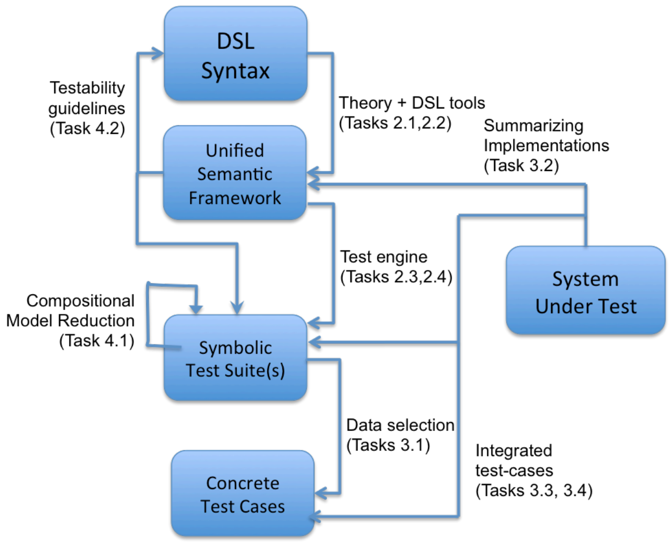

Figure 1: Schematic View of the Method

We plan to apply this theory to concrete DSLs by casting their semantics into this unified domain to show its practical applicability and use it as a proof of concept to our industrial partners. We use concrete examples from financial and automotive domains as our case studies (please see WP5 below).

Based on the unifying semantic framework, we combine MBT with *concolic testing (and symbolic execution)* to obtain efficient and effective test-suites. On the one hand, MBT has traditionally been used as a black-box testing technique. On the other hand, concolic testing solely uses program information (i.e., does not use any models) to steer the testing. By combining the two classes of techniques, one can use high-level models to steer the test-case generation and development process to guarantee a high-level notion of model coverage and simultaneously, exploit information from symbolic execution in order to augment the missing information in the model, e.g., regarding concrete valuation of data parameters. This combination allows for combining model-based and code-based test (data) selection techniques in order to obtain an efficient testing process. It also solves the common problem regarding insufficient concrete information in the abstract models by benefiting from the information available in the implementation under test. In order to make the approach scalable, we exploit compositional reduction techniques (mainly from the area of model-checking), as well as testability guidelines. A schematic view of the approach is depicted in Figure 1. In a nutshell, integrating and applying these recently developed set of techniques will lead to a novel practical framework for applying model-based testing, which is eagerly sought by the embedded software industry.

Concretely, we use a notion of symbolic formal conformance testing (such as [Frantzen+06,Petrenko+04]) as our underlying theory of MBT. We aim at building compositional and symbolic test suites; the compositional structure of the test suites reflects the compositional structure of our semantic model. The symbolic test cases are then subject to various reduction techniques inspired by those already exploited in model-checking (and to some extent already used in concolic testing [Saarkivi+12]). Moreover, the compositional structure of the test suites allows us to perform efficient symbolic reductions and transformations before moving to concrete monolithic test cases.

Testability is also studied at the level of symbolic test cases; it has been observed in our past research that the style of test model specification (e.g., in modeling asynchrony and shared resources) immensely impacts effectiveness of the subsequent MBT. Hence, we come up with concrete criteria for making our test suites and the corresponding reduction techniques more effective. These criteria are translated back into the unified semantic domain, and for our case studies, also to the syntactic domain of the DSL.

We will then move from compositional and symbolic test suites to concrete test cases. To this end, we devise a formal theory of uniformity for data parameters. The proposed theory is reminiscent of traditional functional testing techniques, but has the advantage of automatically detecting the partitions (by comparing the test model with the abstractions built from the implementation under test) and mechanically substituting symbolic data parameters with concrete values while guaranteeing a notion of test adequacy. This research line will be extended with concrete compositionality and testability guidelines for concurrent systems with data, which are first formulated as semantic requirements and through the operational semantics are translated back into syntactic constraints on the DSL models.

Project Structure

The project involves the following researchers from the Center for Research in Embedded Systems (CERES) at Halmstad University:

- Prof.dr. Mohammadreza Mousavi (PI, expertise: MBT and formal semantics)
- Prof.dr. Walid Taha (collaborator, expertise: domain specific languages, embedded systems)
- Postdoctoral candidate (2 years , vacancy, focus area: formal semantics and MBT)

- Ph.D. student (5 years, vacancy, focus area: MBT and concolic testing)

The following internationally renowned researchers are co-proposers of the project:

- Prof.dr. Gul Agha at University of Illinois at Urbana-Champaign, USA, with strong expertise on concolic testing and symbolic execution,
- Dr.ir. Jan Tretmans at Embedded Systems Innovation by TNO and Radboud University of Nijmegen, The Netherlands, with strong expertise on MBT, and
- Prof.dr. Luca Aceto at Reykjavik University, Iceland, with strong expertise on formal semantics and concurrency theory.

The research team is a unique combination of renowned researchers with complementary world-leading expertise, which are all essential in the proposed research program. The co-proposers have already expressed their commitment in collaborating by hosting the researchers employed in this project and bringing research visits to collaborate with the research team at Halmstad. The research team will gather using teleconference regularly on their corresponding tasks.

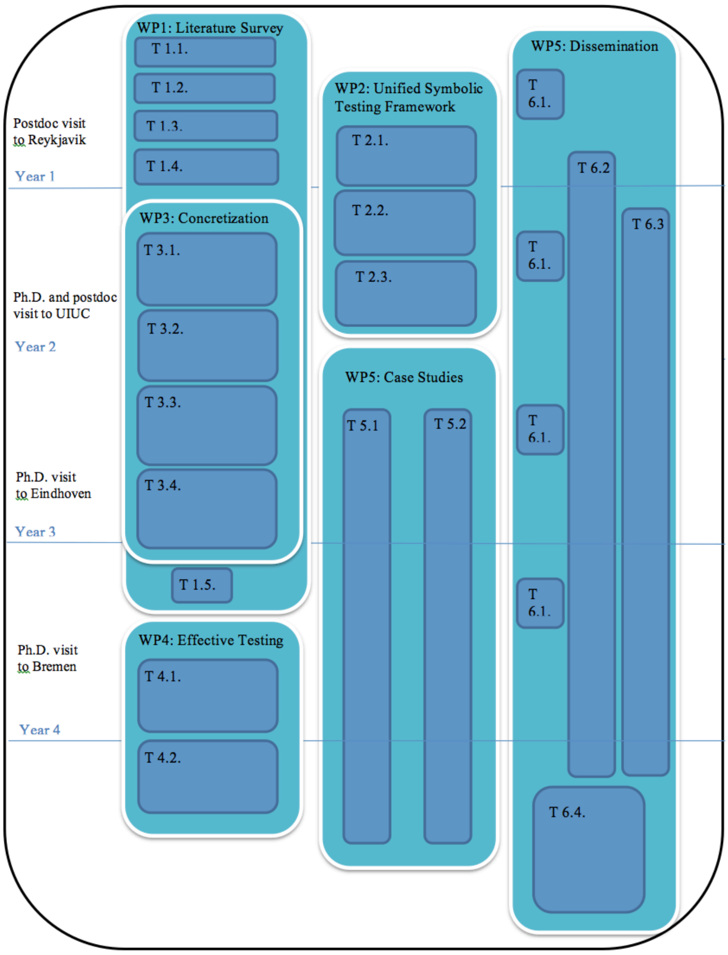

Figure 2: Schematic View of the Project Structure

The PI has been organizing summer schools on testing (HSST 2013 and 2014) in the past 2 years with world-renowned international speakers and there will be 5 instances of the summer school on testing during the project, in which the international collaborators will meet and collaborate with their colleagues in Halmstad. There are also extended research visits planned for the Ph.D. student and the postdoctoral researcher to the institutes of the collaborators.

The project is divided into the following work packages:

- **WP1: Literature Survey.** This work package is dedicated to familiarizing the junior researchers with the background theories for testing, symbolic execution and semantics.
  We divide WP1 further into the following tasks:
  - **T1.1: Survey of Testing and Debugging Techniques:** following a crash course on testing to be offered by the principle investigator based on his prior teaching material on the subject. **Participants:** PI, Postdoc, and Ph.D. **Expected duration:** 2 months (months 1-2) **Deliverable:** tutorial presentations.
  - **T1.2: Survey and Comparison of Formal Conformance Testing Theories, Models and Tools:** studying fundamentals of LTS-based testing [Tretmans08, Broy+05] and FSM-based testing [Lee+94,Yannakakis+95,Broy+05]; using simple case-studies (e.g., based on [Asaadi+11, Keshishzadeh+13]) for a comparison of suitability of theories and tools. We already have survey material from neighboring projects to bootstrap this task (see "Other Grants" section). **Participants:** PI, Postdoc, and Ph.D. **Expected duration:** 5 months (months 3-5) **Deliverable:** Annotated bibliography, paper analyzing empirical data gathered on simple case studies to establish applicability of tools and techniques.

- **T 1.3: Survey of Concolic Testing Tools and Techniques:** studying the theory of symbolic execution and its application in concolic testing. **Participants:** PI, Agha and Ph.D. **Expected duration:** 4 months (months 6-9) **Deliverable:** Survey paper.
- **T 1.4: Survey of Test (Data) Selection and Coverage Criteria:** surveying test-data selection techniques and test-case selection from symbolic models in MBT. **Participants:** PI, Tretmans and Ph.D. **Expected duration:** 3 months (months 10-12) **Deliverable:** Survey paper.
- **T 1.5: Survey of Testability Criteria:** studying the literature on testability of implementations, as well as recent attempts to formulate testability guidelines based on specifications. The goal is to survey these two lines of research. **Participants:** PI and Ph.D. **Expected duration:** 3 months (months 36-38) **Deliverable:** A technical report (annotated bibliography).

- **WP2: Unified Symbolic Testing Framework.** The goal of this work package is to come up with a operational semantic framework that provides the basic ingredients for generating test-cases from any language with operational semantics in a given form. The framework will provide sufficient structure in the labels of the operational semantic transitions that can clearly indicate the input and output interactions, parameterized with symbolic data to cater for the semantics of models, implementations and test-cases.
  - **T2.1. Semantics Meta-Framework for Testing**: This task includes fixing the semantic domain which will serve as the unifying symbolic framework for our test models. **Participants:** PI, Aceto and Postdoc. **Expected duration:** 6 months (months 6-11) **Deliverable:** Survey paper, and a research paper on transformation among different existing semantic models while preserving / reflecting conformance relation.
  - **T2.2. Case Study on Semantics**: we shall experiment with our semantic domain by implementing the semantics of a DSL on which we have already been performing testing exercises (e.g., our own past models [Asaadi+11, Keshishzadeh+13] or those we have recently received from our industrial partners, see below); there exists tool support (parser, validation and verification, test-case generation) already for these DSLs and we re-use part of the tool / background knowledge about the tooling and customize such tools in order to support our semantic meta-framework and deriving necessary properties for the specified semantics. **Participants:** PI, Aceto, Taha and Postdoc. **Expected duration:** 6 months (months 12-17) **Deliverable:** An extensible DSL environment (such as an Eclipse plugin) for DSL specification (syntax and validation rules) supported by a compiler into the unified semantic framework. (Combined with 2.3: a tool paper.)
  - **T2.3. Generic Test-Case Generation Engine**: In this task the operational semantics rules defined in the developed environment of Task 2.2 will be used to generate symbolic test-cases. (The format of symbolic test-cases are also to be fixed in this task.) Symbolic test-cases will be turned into concrete test-cases by using constraint solving (e.g., SMT). We do not intend to build in any intelligence regarding the quality and coverage of concrete test-cases in this task; this task will only serve as the basic common ground for the subsequent implementation T 3.4. **Participants:** PI, Tretmans, and Postdoc. **Expected duration:** 6 months (months 18-23) **Deliverable:** An extension of the environment from T2.2 for test-case generation with sufficient documentation. A tool paper describing the environment.
- **WP3: Concretization**: The goal of this work package is to extend the test-case generation framework of WP2 in order to take the behavior of the implementation into account and use this information to augment the symbolic models and steer the test-cases (data) selection.
  - **T3.1. Test data selection:** In this task, we first define different notions of adequacy for concrete test-cases with respect to symbolic models of specification and implementation. These notions are reminiscent of different functional testing methods as well as adequacy criteria studied and surveyed in T1.5 and will adapt and formalize them to our setting for MBT. **Participants:** PI, Tretmans, Agha and Ph.D. **Expected duration:** 6 months (months

12-17) **Deliverable:** Article on formal criteria for data selection in symbolic models (from T2.1) for our notions of test adequacy.

  - **T3.2. Summarizing implementations:** In this task symbolic execution techniques are used to summarize implementation behavior with respect to relevant parameters / models into the level of abstraction needed to study adequacy of test data selection. This task will start by assuming an operational semantic model of implementation (akin to those for models from T2.1) and will show its feasibility by taking a concrete case from our target implementation domains (e.g., programming and system-level design languages). The summaries are hence also expected to have the same formal structure as the semantic domain of our DSLs and hence, can be treated uniformly using our to-be-developed theories and tools. **Participants:** PI, G. Agha and Ph.D. **Expected duration:** 6 months (months 18-23) **Deliverable:** An extension of the environment from T2.2 (and T2.3) for summarizing implementations with respect to relevant parameters / models. test-case generation with sufficient documentation. A tool paper describing the environment.
  - **T3.3. Integrated Test-Case Generation:** This task involves integrating the behavioral information from the model and from the implementation summaries in order to generate efficient test-suites guaranteeing the notions of adequacy defined in T 3.1. **Participants:** PI, J. Tretmans, and G. Agha and Ph.D. **Expected duration:** 6 months (months 24-29) **Deliverable:** An algorithm for concolic model-based test-case generation. An article containing the algorithm, proof of its correctness (soundness, adequacy) and analyzing its complexity.
  - **T3.4. Extending the Engine:** This task involves implementing the devised algorithm of T3.3. in the testing engine for DSLs (by combining T2.3 and T3.2). **Participants:** PI, G. Agha and Ph.D. **Expected duration:** 6 months (months 30-35) **Deliverable:** An extension of the environment from T2.2 (and T2.3) for summarizing implementations with respect to relevant parameters / models. test-case generation with sufficient documentation. A tool paper describing the environment.
- **WP4: Effective Testing:** The goal of this package is to devise guidelines for compositionality and testability.
  - **T4.1. Compositional reduction techniques:** The goal of this task is devise compositionality meta-theorems that allow for decomposing test-cases of the system efficiently (without exponential blow up) into the test-cases of its components while dealing with concurrency issues. The goal also includes a sequence of reduction techniques with proven evidence in model reduction. **Participants:** PI, Aceto, Tretmans and Ph.D. **Expected duration:** 6 months (months 39-44) **Deliverable:** A paper formulating a general semantic meta-theorem about compositionality and model reduction and applying it to obtain concrete results for a DSL.
  - **T4.2. Testability guidelines:** The goal of this task is to investigate the effect of various semantic conditions on both models and their implementation on the size of the generated adequate test-case. The meta-theorems formulated for the semantic conditions have to be translated back in terms of a concrete theorem for an example DSL. **Participants:** PI, Tretmans and Ph.D. **Expected duration:** 6 months (months 45-50) **Deliverable:** A paper formulating a general semantic meta-theorem about testability and translating it back into a concrete syntactic theorem for a DSL.
- **WP5: Case Studies**
  - **T5.1. Financial domain:** We use a simplified model of a funds transfer switch [Asaadi+11], of which we both have a symbolic model (in UML) and a Java implementation as our first sandbox for both random generation of test-cases as well as concolic model-based testing (outcome of T3.4) and enhancements thereof (T4.1 and T4.2).
  - **T 5.2 Automotive domain:** We use available symbolic models for automotive from [TurnIndic11] and from our industrial partners Quviq and ArcCore (see “National and international collaboration” below).

- **WP6: Dissemination:**
    - **T6.1. Summer School on Testing**: The PI has already organized 2 editions of the Halmstad Summer School on Testing (HSST 2013 and 2014) with renowned international speakers. We envisage 5 subsequent editions in the period of the project.
    - **T 6.2. Presenting at and attending conferences and workshops:** Typical venues include ICST, ISSRE, ASE, ICSE, ETAPS (FASE,ESOP), and ACM SAC (SVT) conferences as well as MBT and A-MOST workshops.
    - **T 6.3. Publishing at journals.** Typical outlets include SoSym, IEEE TSE, ACM TOSEM, and Software Testing, Verification and Reliability Journals. We have accommodated in the budget that all our journal publications will be published using the open access facilities provided by the respective publishers.
    - **T 6.4. Writing up a Ph.D. thesis**

A schematic view of the project structure is given in Figure 2.

Significance

Problems with testing and validation are currently pervasive in most embedded systems development environments. These have been witnessed first hand by the PI in his various interactions with embedded systems industry. MBT usually calls for abstract models (in terms of finite-state machines, or labelled transition systems), which focus on the interface behaviour of the system under test (SUT). Currently, lack of generic models, such as the type of state machines typically used in MBT, hampers read application of MBT in practice. Moreover, such generic models are often meant to hide the details about the system state (e.g., variables and their exact valuations, cf. [Broy+05,Tretmans08]). Hence, they do not provide the level of detail required to apply such models in testing practical applications and much complementary information has to be added to the abstract test-cases (e.g., by the so-called ``test adapters'') to apply them to the implementations under test. This process is a very time-consuming and error-prone task, which further bars wide applicability of MBT. As a third lacking aspect, current MBT techniques usually do not use any white-box information to steer the test-case generation process. By addressing these issues, we provide a solution for the increasing demand for mechanized testing processes which is eagerly sought by the embedded software community. Addressing this issues and providing a theoretical framework with sufficient tool support to address these issues will therefore significantly improve the current practice of testing and the present proposal aims at this goal.

Currently, no theoretical or practical framework is available to overcome these problems in their entirety. Some MBT tools, such as the SpecExplorer framework of Microsoft [SpecExplorer], provide some support for integrating data with behavioural modelling. However, data selection algorithms that can be used in such tools are primitive and only provide support for some standard data selection mechanisms. In our experiments (cf. [Vishal+12]), none of the provided techniques were applicable due to the combinatorial explosion of the combination of data parameters and sheer complexity of practical systems. (This has been observed in earlier experiments with other tools, see, for example [Bauer+09].) We believe that the combination of conolic testing with MBT (based on DSLs) will be a considerable step beyond the state of the art. Also formulating testability and compositionality meta-theorems, particular for concurrent systems is an essential step in managing the complexity of concurrent systems.

Preliminary Results

Problems with current testing practices have been experienced first-hand by the PI through various collaborations with the industry (e.g., in a particular embedded systems company, the routine regression tests took more than one night on their testing farm and hence, continuous integration became impossible). We have been experimenting with various aspects of the proposed research in the past few years. In [Vishal+12,Asaadi+11,Keshishzadeh+13], we report on our attempts to replace the current ad-hoc practice of testing with more structured MBT-based processes.

In [Noroozi+13-1] and [Noroozi+13-2], we have developed, respectively, compositionality and testability criteria in a distributed system setting. Other related pieces of work (some by the involved research team) include [Bijl+03,Villa+12]. All such criteria are hitherto formulated as semantic properties on abstract behavioral domains (input-output labeled transition systems). It remains to be seen how these criteria can be translated into symbolic semantic domains (which is a necessary extension for practical applicability) and more importantly, to syntactic criteria in high-level specification languages such as DSLs.

National and international collaboration

In addition to the research team in Halmstad and the international collaborators, the PI has established a network of collaborators in the subject area both in Sweden and abroad.
In Sweden the PI collaborates with Chalmers University of Technology (prof.dr. John Hughes), Quviq AB (dr. Thomas Arts), and ArcCore AB (Johan Ekberg). This collaboration is centered around case studies, models and tools for the PI's ongoing research on applying model-based diagnosis to automotive systems (MB-CAAS project, see below).
Also the PI has an active collaboration with the group of prof.dr. Jan Peleska at the University of Bremen, the group of prof.dr. Holger Hermanns at Saarland University and several industrial partners in the Netherlands (NSpyre: Rachid Kerrazi and Philips Healthcare: dr. Frank van der Linden) all in the domain of MBT. The Ph.D. student will bring a visit to prof. Peleska's group in her/his 4th year to benefit from their vast experience in tool development and application of MBT to large case studies.

Other Grants

The project will take place in the newly established chair of the PI. The chair has already received a strategic investment from the vice chancellor of Halmstad University, which resulted in a project on MBT for Software Product Lines (MBT4SPL, 2013-2019). Two researchers (a postdoctoral researcher from 2013 to 2015 and a Ph.D. student from 2014 to 2019) have been employed on this project.
The PI has a project proposal with Knowledge Foundation (subject to approval) on model-based consequence analysis for automotive systems. The project will finance a postdoctoral researcher for 3 years (2015-2018).
Both MBT4SPL and MB-CAAS are defined in complementary areas to that of the present proposal and will create a rich and broad collaborative platform for the PI and the involved researchers in all 3 projects.

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[Noroozi+13-1] N. Noroozi, M.R. Mousavi, and T.A.C. Willemse. Decomposability in Input Output Conformance Testing. Proc. of MBT, vol. 111 of EPTCS, 2013.

[Noroozi+14-1] N. Noroozi, M.R. Mousavi, and T.A.C. Willemse. Complexity of Input-Ouput Conformance Testing. In Proc. of FACS'13, LNCS, Springer, 2014. To appear.

[Noroozi+14-2] N. Noroozi, R. Khosravi, M.R. Mousavi, and T.A.C. Willemse. Synchrony and Asynchrony in Conformance Testing. J. SoSym, Springer, 2014. In press.

[Peleska+13] Jan Peleska and Wen-ling Huang: Exhaustive Model-Based Equivalence Class Testing. In Proceedings of the ICTSS2013. Springer, LNCS 8254, pp.49-64, 2013.

[Petrenko+04] A. Petrenko, S. Boroday, R. Groz, Confirming configurations in EFSM testing, IEEE TSE 30(1):29–42, 2004.

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[Rosu+10] G. Rosu and T.F. Serbanuta. An Overview of the K Semantic Framework. JLAP 79(6):397-434, 2010.

[Sandler+10] K. Sandler, et al. Killed by Code: Software Transparency in Implantable Medical Devices. Software Freedom Law Center, 2010.

[Saarkivi+12] Olli Saarikivi, Kari Kähkönen, Keijo Heljanko: Improving Dynamic Partial Order Reductions for Concolic Testing. In Proc. of ACSD'12, pp. 132-141, IEEE, 2012.

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[Vishal+12] V. Vishal, M. Kovacioglu, R. Kherazi, M.R. Mousavi. Integrating Model-Based and Constraint-Based Testing Using SpecExplorer. In Proc. of MoTiP'12, IEEE, 2012.

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VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

Title of research programme
Effective model-based testing of concurrent systems

Appendix B

Curriculum vitae

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CVs (Appendix B)

Mohammadreza Mousavi (Principal Investigator)

Higher Education Degrees

2001 M.Sc., Computer Engineering (Software), Sharif University of Technology, Tehran, Iran.

1999 B.Sc., Computer Engineering (Software), Sharif University of Technology, Tehran, Iran.

Doctoral Degree

2005 Ph.D., Computer Science, Eindhoven University of Technology, Eindhoven, The Netherlands. (Thesis Supervisors: prof.dr.ir. J.F. Groote and prof.dr. G.D. Plotkin)

Postdoctoral Positions

2006-2007 Postdoctoral Researcher, Icelandic Center of Excellence for Theoretical Computer Science, School of Computer Science, University of Reykjavik, Reykjavik, Iceland. (Supervisors: prof.dr. L. Aceto and prof.dr. A. Ingolfsdottir)

Present Position

March 2013-Present Professor of Computer Systems Engineering, Center for Research on Embedded Systems, Halmstad University, Sweden.

September 2013-Present Chairman of the Ph.D. Program Steering Group, School of Information Science, Computer Science and Electrical Engineering, Halmstad University, Sweden.

Past Positions

2005-2013 Associate Professor (till 2012: Assistant Professor), Department of Computer Science, Eindhoven University of Technology, The Netherlands.

2011-2013 Visiting Faculty Member, Embedded Software Group, Faculty of Electrical Engineering, Mathematics, and Computer Science (EWI), Delft University of Technology, The Netherlands.

2010-2013 Program Director, Masters Program in Embedded Systems, Eindhoven University of Technology, The Netherlands.

2005-2006 Assistant Professor (part-time), Department of Electrical Engineering, Eindhoven University of Technology, The Netherlands.

Supervision

Main Supervisor for:

2013-2015 Harsh Beohar (Postdoctoral Researcher, Center for Research on Embedded Systems, Halmstad University.) Research Subject: Model-Based Testing for Software Product Lines.

2014-Present Mahsa Varshosaz (Ph.D. Student, School of Information Science, Computer and Electrical Engineering, Halmstad University.) Research Subject: Model-Based Testing for Software Product Lines. Expected graduation: 2019.

2010-Present Neda Noroozi (Ph.D. Student, Dept. of Computer Science, TU/Eindhoven.) Research Subject: Model-Based Testing of Financial Systems. Expected graduation: November 2014.

2007-2011 Matthias Raffelsieper (Ph.D. Student, Dept. of Computer Science, TU/Eindhoven.) Thesis Title: Cell Libraries and Verification. Graduated: November, 2011.

2007-2011 Mummad Atif (Ph.D. Student, Dept. of Computer Science, TU/Eindhoven.) Thesis Title: Formal Modeling and Verification of Distributed Failure Detectors. Graduated: September 2011.

2010-2011 Yogesh Khambia, (Professional Doctorate (TOIO) Student, Dept. of Computer Science, TU/Eindhoven.) Thesis Title: Redesigning Test Automation Data Model (for Oce Copier Machines). Graduated: September 2011.

2010 Assad Saleem, (Professional Doctorate (TOIO) Student, Dept. of Computer Science, TU/Eindhoven.) Thesis Title: CARM Light: Software Architecture for the Motion Control System. Graduated: October 2010.

2008-2009 Jorge Crespo Cedeno, (Professional Doctorate (TOIO) Student, Dept. of Computer Science, TU/Eindhoven.) Thesis Title: Making Lighting Control Systems Aware of Human Locations. Graduated: September 2009.

Member of Ph.D. Committee for:

2012-Present Essayas Gebrewahid (Ph.D. Student, Member of the Support Committee, School of Information Science, Computer and Electrical Engineering, Halmstad University.)

2009-2011 Matteo Cimini, (Ph.D. Student, Member of Thesis Committee. Supervised by Luca Aceto. Dept. of Computer Science, Reykjavik University.)

Gul Agha

Higher Education Degrees

M.Sc. in Computer and Communication Science, University of Michigan at Ann Arbor, USA.

AM in Psychology, University of Michigan at Ann Arbor, USA.

Doctoral Degree

1985, Ph.D. in Computer and Communication Science, University of Michigan, USA.

Present Position

Professor, Department of Computer Science, University of Illinois at Urbana-Champaign.

Research Professor in the Coordinated Science Laboratory, and the Information Trust Institute at the University of Illinois atUrbana-Champaign.

Past Positions

1987-1989 Research Scientist, Department of Computer Science, Yale University, USA.

1983-87 Researcher, Artificial Intelligence Lab, Massachusetts Institute of Technology (MIT), USA.

Supervision

Current:

Peter Dinges, Ph.D. Student, Univiersity of Illinois at Urbana Champaign, Subject: “Coordination Models for Concurrent Systems”.

Minas Charalambides, Ph.D. Student, University of Illionis at Urbana-Champaign, Subject: “Ease of Programming and Performance Optimization for Actor Coordination”.

Rajesh Kumar Karmani, Ph.D. Student, University of Illionis at Urbana-Champaign, Subject: “Model Checking and Testing Actor Models”.

Parya Moinzadeh, Ph.D. Student, University of Illionis at Urbana-Champaign, Subject: “Structural Health Monitoring”.

Reza Shiftehfar, Ph.D. Student, University of Illionis at Urbana-Champaign, Subject: “Adaptive Programming Framework for Mobile Cloud-Computing”.

Ashish Vulimiri. Ph.D. Student, University of Illionis at Urbana-Champaign.

Past:

(26 in total, only the most recent ones mentioned below)

2011 Kirill Mechitov, Department of Computer Science, University of Illinois at Urbana-Champaign, “A Service-Oriented Architecture for Dynamic Macroprogramming of Sensor Networks”.

2011 Liping Chen, Department of Computer Science, University of Illinois at Urbana-Champaign, Thesis Title: “Conformance Preserving Data Dissemination for Large-Scale Peer to Peer Systems”.

2011 Vijay AR Korthikanti. Department of Computer Science, University of Illinois at Urbana-Champaign, Thesis Title: “Towards Energy-Performance Trade-off Analysis of Parallel Applications”.

2010 Vilas Shekhar, Department of Computer Science, University of Illinois at Urbana-Champaign, Thesis Title: “Reducing the costs of bounded-exhaustive testing”.

2009 MyungJoo Ham, Department of Computer Science, University of Illinois at Urbana-Champaign, Thesis Title: “Market-based Coordination and Auditing Mechanisms for Self-Interested Multi-Robot Systems”.

2009 Sameer Sundresh, Department of Computer Science, University of Illinois at Urbana-Champaign Thesis Title: “Request-Based Mediated Execution”.

2004 Nadeem Jamali, Department of Computer Science, University of Illinois at Urbana-Champaign

2001 Carlos Varela, Department of Computer Science, University of Illinois at Urbana-Champaign

1998 Nalini Venkatasubramanian, Department of Computer Science, University of Illinois at Urbana-Champaign

1997 Anna Patterson, Department of Computer Science, University of Illinois at Urbana-Champaign

1997 Wooyoung Kim, Department of Computer Science, University of Illinois at Urbana-Champaign

1997, Rajendra Panwar, Department of Computer Science, University of Illinois at Urbana-Champaign

1997 Shangping Ren, Department of Computer Science, University of Illinois at Urbana-Champaign

1996 Daniel Sturman, Department of Computer Science, University of Illinois at Urbana-Champaign

1995 Svend Frolund, Department of Computer Science, University of Illinois at Urbana-Champaign

Walid Taha

Higher Education Degrees

B.Sc. in Computer Engineering, Kuwait University, 1993.

Doctoral Degree

Ph.D. in Computer Science and Engineering, Oregon Graduate Institute, December 1999. Multi-Stage Programming: Its Theory and Applications. Advisor: Prof. Tim Sheard. Nominated for the ACM Distinguished Dissertation Award.

Present Position

2010 - Present Full Professor, Halmstad University, Sweden

2010 - Present Adjunct Professor and Research Scientist, Rice University, USA

Past Positions

2002 - 2010 Assistant Professor, Rice University, Houston, USA.

2000 - 2002 Research Faculty, Yale University, New Haven, USA

1999 - 2000 Post-doc, Chalmers, Gothenburg, Sweden

1997 Intern, Bell Laboratories, Lucent Technologies, New Jersey, USA

Supervision

Ph.D. Students / Graduates:

Adam Duracz, Center for Research on Embedded Systems, Halmstad University, Expected graduation: 2016.

Yingfu Zeng, Department of Computer Science, Rice University, Expected graduation: 2015.

Jun Inoe, Department of Computer Science, Rice University, 2012.

Fulong Cheng, Northwestern Polytechnical University, China, 2011.

Cherif Salama, Department of Computer Science, Rice University, 2010.

Raj Bandyopadhyay, Department of Computer Science, Rice University, 2009.

Postdoctoral Students / Researchers:

2012-Present Jan Duracz, Center for Research on Embedded Systems, Halmstad University.

2012-Present Jawad Masood, Center for Research on Embedded Systems, Halmstad University,

2012-Present Kevin Atkinson, Department of Computer Science, Rice University.

2010 Paul Brauner, Department of Computer Science, Rice University.

2008-2010 Edwin Westbrook, Department of Computer Science, Rice University.

2008-2009 Ronald Garcia, Department of Computer Science, Rice University.

2004-2006 Jeremy Siek, Department of Computer Science, Rice University.

2004-2006 Emir Pasalic, Department of Computer Science, Rice University.

2002-2004 Kedar Sawadi, Department of Computer Science, Rice University.

Jan Tretmans

Higher Education Degrees

MSc. Electrotechnical Engineering, specialization Computer Science, University of Twente, Enschede (NL), 1980-1986.

Master thesis: "Development of a LOTOS Static Semantics Checker Using Attributed Grammars" (cum laude); supervisor: Prof. Dr. Ir. C.A. Vissers.

Doctoral Degree

Ph.D. Computer Science, University of Twente, Enschede, The Netherlands.

Dissertation: "A Formal Approach to Conformance Testing", December 10, 1992; promoter: Prof. Dr. H. Brinksma.

Present Position

Scientist at TNO Embedded Systems Innovation, Eindhoven, The Netherlands.

Assoc. Prof. at Radboud University, Nijmegen, The Netherlands.

Past Positions

2006-Present Research Scientist, TNO – Embedded Systems Innovation (Embedded Systems Institute), Eindhoven (NL) (part time: 80%).

2002-Present Associate Professor, Radboud University Nijmegen (NL), Institute for Computer and Information Science (since 2006 part time: 20%).

2008, Thales Netherlands B.V.,working on integration and testing of large, complex systems.

2001-2002 Assistant Professor, University of Twente, Enschede (NL), Dept. of Computer Science, Formal Methods & Tools Group.

1997-1998 CMG Den Haag B.V., Consultant on the use of formal methods.

1995-2001 Research Associate, University of Twente, Enschede (NL), Dept. of Computer Science, Formal Methods & Tools Group.

1993-1994 Postdoctoral research fellow, ERCIM (European Research Consortium for Informatics and Mathematics), visiting Sintef-Delab, Trondheim, Norway, Forth-ICS, Heraklion, Greece, and GMD, Sankt Augustin, Germany.

1986-1992 Research Assistant, University of Twente, Enschede (NL), Dept. of Computer Science, Tele-Informatics and Open Systems group.

Supervision

Current:

M. Volpato, Ph.D. Stuent, Thesis: “Test Selection for Model-Based Testing”, Radboud University, Nijmegen (NL), planned 2015.

L. Frantzen, Thesis: “Symbolic Model-Based Testing”, Radboud University, Nijmegen (NL), expected 2013.

Past:

Machiel van der Bijl, Thesis: “On Changing Models in Model-Based Testing”, University of Twente, May 12, 2011.

N. Goga, Ph.D. Student, Thesis: “Control and Selection Techniques for the Automated Testing of Reactive Systems”, Eindhoven University of Technology (NL), October 7, 2004.

A.W. Heerink, Ph.D. Student. Thesis: “Ins and Outs in Refusal Testing”, University of Twente (NL), May 8, 1998.

Luca Aceto

Higher Education Degrees

Laurea (MSc) in Computer Science, July 1986, University of Pisa, Italy.

Doctoral Degree

DPhil Computer Science, July 1991, University of Sussex, Supervisor: Prof. Matthew Hennessy. Distinguished Dissertations in Computer Science award 1991, published by Cambridge University Press.

Present Position

2004-Present Full Professor of Computer Science, Reykjavik University, Reykjavik, Iceland.

Past Positions

1996-2006 Department of Computer Science, Aalborg University, Associate Professor

1995 Afdeling for Matematik og Datalogi, Aalborg University, Visiting Research Professor

1994-1996 BRICS (Basic Research in Computer Science), Centre of the Danish National Research Foundation, Afdeling for Matematik og Datalogi, Aalborg University, BRICS Senior Research Fellow

1992-1996 School of Cognitive and Computing Sciences, University of Sussex, Lecturer in Computer Science and Artificial Intelligence

1991-1992 Hewlett-Packard Laboratories, Pisa Science Center, Research Fellow

1991 Centre de Mathematiques Appliqúees, INRIA-Sophia Antipolis, Professeur Invité

Supervision

Ph.D. Students:

At Reykjavik University:

2010-2013 Georgiana Caltais, School of Computer Science, Reykjavik University, Thesis title: Coalgebraic Tools for Bisimilarity and Decorated Trace Semantics

2010-2013 Eugen-Ioac Goriac, School of Computer Science, Reykjavik University, Thesis title: Axiomatizations from Structural Operational Semantics: Theory and Tools.

2009-2011 Matteo Cimini, School of Computer Science, Reykjavik University, Thesis title: Meta-theory of Structural Operational Semantics.

At Sussex University (1992-1996):

Amer Al-Rawas, William Ferreira, Gary Straines and Joe Wood.

VETENSKAPSRÅDET
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Appendix C

List of publications

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Publication list (Appendix C)

Apart from the most cited publications,
only publications from the last eight years are included.
Bibliographical data are from Google Scholar.
The most (recent) relevant papers are marked with a (*).

Five Most Cited Publications:

- A.H. Ghamarian, M.C.W. Geilen, S. Stuijk, T. Basten, A.J.M. Moonen, M.J.G. Bekooij, B.D. Theelen, and M.R. Mousavi. Throughput analysis of synchronous data flow graphs. In Proc. of ACSD'06, pp. 25—36, IEEE, 2006. (Number of citations: 153)
- M.R. Mousavi, M.A. Reniers, and J.F. Groote. SOS formats and meta-theory: 20 years after. Theoretical Computer Science 373 (3): 238--272, 2007. (Number of citations: 52).
- M.R. Mousavi, M.A. Reniers, and J.F. Groote. Notions of bisimulation and congruence formats for SOS with data. Information and Computation 200 (1): 107--147, 2005. (Number of citations: 44)
- A.H. Ghamarian, M.C.W. Geilen, T. Basten, B.D. Theelen, and M.R. Mousavi. Liveness and boundedness of synchronous data flow graphs. In Proc. of FMCAD'06, pp. 68—75, IEEE, 2006. (Number of citations: 39)
- M.R. Mousavi, P. Le Guernic, J.P. Talpin, S.K. Shukla, and T. Basten. Modeling and validating globally asynchronous design in synchronous frameworks. In Proc. of DATE'04, pp. 384—389, IEEE, 2004. (Number of citations:35)

Book

- J.F. Groote and M.R. Mousavi. Modeling and Analysis of Communicating Systems. MIT Press. 2014. In Press. ISBN 978-0-262-02771-7. **(*)**

Journal Publications

- N. Noroozi, R. Khosravi, M.R. Mousavi, and T.A.C. Willemse. Synchrony and Asynchrony in Conformance Testing. Software and Systems Modeling, Springer, 2014. In Press. Available online. (1 citation) **(*)**
- N. Khakpour, S. Jalili, C. Talcott, M. Sirjani and M.R. Mousavi. Formal Modeling of Evolving Self-Adaptive Systems. Science of Computer Programming, 78(1):3-36, Elsevier, 2012. (12 citations)
- L. Aceto, M. Cimini, A. Ingolfsdottir, M.R. Mousavi and M. A. Reniers. Rule Formats for Distributivity. Theoretical Computer Science, 458:1-28, Elsevier, 2012. (8 citations)
- L. Aceto, A. Birgisson, A. Ingolfsdottir, M.R. Mousavi and M.A. Reniers. Rule Formats for Determinism and Idempotence. Science of Computer Programming, 77(7-8):889-907, Elsevier, 2012. (17 citations)

- M. Rfafelsieper, M.R. Mousavi and H. Zantema. Long-Run Order-Independence of Vector-Based Transition Systems. IET Computers & Digital Techniques, 5(6):468-478, Institution of Engineering and Technology (IET), 2011. (1 citation)
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- H. Hojjat, M.R. Mousavi, and M. Sirjani. Formal Analysis of SystemC Designs in Process Algebra, Fundamenta Informaticae, 107(1):19-42, IOS Press, 2011. (1 citation)
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VETENSKAPSRÅDET
THE SWEDISH RESEARCH COUNCIL

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2014-45212-115235-57

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Appendix N

Budget and research resources

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Budget and resources (Appendix N)

The principal investigator (PI) has started his position in 2013 leading the new chair of Computer Systems Engineering. His main research subject is Model-Based Testing and Verification and as such will spend 80% of his full-time appointment on this research topic. The PI has applied for research funding for 20% of his time in the present proposal, which only covers his direct research effort. The effort required for the supervision of the junior researchers (estimated at 15% of the full time appointment) will be covered by Halmstad University. The requested budget for the salary of the junior researchers (Ph.D. and postdoc) will cover their research time. (The Ph.D. and the postdoc will spend 25% and 20% of their time on educational activities, respectively.) The salaries mentioned in the following table include 47% salary overheads.

The research effort of the collaborators is funded by their respective institutes and they have expressed commitment in hosting and supervising the junior researchers in the duration of the project. The project will provide funding for the visits of the international collaborators to Halmstad. We plan to consolidate these visits with the annual summer school on testing organized in Halmstad. We will dedicate a session of this summer school to the results of the present project.

As of June 2013, the PI has hired a postdoctoral researcher on applying MBT to product lines (MBT4SPL). Also the recruitment for a Ph.D. student within MBT4SPL is concluded and the selected candidate starts her research as of June 1, 2014. The project is financed by a strategic funding provided by the Vice Chancellor of Halmstad University.

Also till the end of 2014, the PI supervises a Ph.D. student at TU/Eindhoven working on applying MBT to asynchronous and parallel systems (funded directly by industry).

The PI has a grant proposal (Model-Based Consequence Analysis for Automotive Systems – MBCAAS) with the Knowledge Foundation in Sweden on model-based fault diagnosis for automotive applications involving two companies (Quviq and ArcCore). The PI has already started collaborating with these companies on concrete case studies, which will also be used as case studies for the present project. The MBCAAS project is expected to commence in January 2014 and will create a very fruitful synergy with the present project by providing more practical context and case studies.

The PI has applied for an EU FP7 Career Integration Grant on tooling for MBT. The grant application has passed the threshold and is being considered for funding; if awarded, will provide a lump sum of 100k Euros over the period of 4 years starting from late 2014. The grant will be spent on funding master students who will apply MBT to various practical case studies and gather empirical data, which can provide useful input to the present project.

Budget Item	Description	Amount
Ph.D. St. (2015-2016)	Salary First Year (75%)	476 kSEK
Ph.D. St. (2016-2017)	Salary Second Year (75%)	497 kSEK
Ph.D. St. (2017-2018)	Salary Third Year (75%)	540 kSEK
Ph.D. St. (2018-2019)	Salary Fourth Year (75%)	572 kSEK
Ph.D. St. (2019-2020)	Salary Fifth Year (75%)	594 kSEK
Subtotal Ph.D. Student (2014-2019)	**Salary (75%, excl. teaching)**	**2,679 kSEK**

Postdoc. (2015-2016)	First Year (80%)	731 kSEK
Postdoc. (2016-2017)	Second Year (80%)	753 kSEK
Subtotal Postdoc Student (2014-2016)	**Salary (80%: excl. 20% teaching)**	**1484 kSEK**
Full Prof. (2015-2019)	Yearly Salary (20%)	293 kSEK
Subtotal Full Prof. (2015-2019)	**Salary (20%), including 3% yearly salary increase**	**1554 kSEK**
Extended visits Ph.D. student and postdoc (2015-2018)	Ticket and lodging expenses for visits to the collaborators' groups per extended visit	35 kSEK
Conference and workshop (2015-2019)	Ticket and lodging expenses per conference visit	15 kSEK
Publication costs	Open access publication per publication	10 kSEK
Hosting collaborators	Ticket and lodging expenses per visitor	25 kSEK
Subtotal travel and publication budget (2014-2019)	**3 extended visits for the Ph.D. student, 2 extended visits for the postdoc, 3 visits by the collaborators, 5 open access journal publications, 10 conference visits for project member**	**450 kSEK**
Office Costs (2014-2019)	Yearly office costs for the Ph.D. student and the postdoc	66 kSEK
Subtotal Office Costs	**5 years of office costs for the Ph.D. student and 2 years for the postdoc**	**462 kSEK**
Total	**Salary and Travel**	**6,629 kSEK**

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Project title
Effective model-based testing of concurrent systems

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Research grants NT April 9, 2014
Project Research Grant
*Övrigt generellt
Högskolan i Halmstad

Appendix S

Signatures

2015	2016	2017	2018	2019
1732	1793	1016	1034	1054

2015-01-01 -- 2019-12-31

Applicant **Date**

Head of department at host University **Clarifi cation of signature** **Telephone**

A signature on the application is required not only from the applicant but also from the authorised representative of the administrating organisation/institution or equivalent (normally the head of the department or establishment where the research is to be conducted). The signature confirms that the department can accommodate the proposed research, position or equipment; that the costing in the application is approved for the department's part, that any proposed experimentation on human or animal subjects has been reported, and that the applicant has reported any secondary occupations and commercial ties (s)he may have, and nothing inconsistent with good research practice has thereby emerged. The applicant must have discussed these conditions with the representative of the administrating organisation/institution or equivalent before the latter approves and signs the application.

NOTE the exceptions!
Please note that a different procedure applies for the following types of grants:

- Infrastructure- Operation Grants
- Infrastructure- Grants for Expensive Equipment
- Infrastructure- Grants for Large Databases
- Framework Grant SIMSAM
- International Recruitment

For these types of grants the vice-chancellor, instead of the head of department, must sign Appendix S. Thereby (s)he confirms the commitments of the administrative organization. The details are specified in the Call for Proposals, published at www.vr.se.

Vetenskapsrådets noteringar
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