Vetenskapsrådet

# *Application*

2015-03-31

**2015-03984 Fabian, Martin NT-14**

## Information about applicant

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## Information about application

**Call name:** Forskningsbidrag Stora utlysningen 2015 (Naturvetenskap och teknikvetenskap)

**Type of grant:** Projektbidrag

**Focus:** Fri

**Subject area:**

**Project title (english):** COMBAT - Compositional Model Based Test Generation

**Project start:** 2016-01-01

**Project end:** 2019-12-31

**Review panel applied for:** NT-14, NT-2, NT-1

**Classification code:** 20207. Inbäddad systemteknik, 20202. Reglerteknik, 10201. Datavetenskap (datalogi)

**Keywords:** Testning, Formella metoder, Kompositionella metoder, Säkerhetskritiska system

## Funds applied for

| **Year:** | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| **Amount:** | 1,467,000 | 1,484,000 | 1,532,000 | 1,582,000 |

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**Descriptive data**

## Project info

### Project title (Swedish)*

COMBAT - Kompositionell modellbaserad testgenerering

### Project title (English)*

COMBAT - Compositional Model Based Test Generation

### Abstract (English)*

The complexity of engineered products is ever increasing, and with that follows an increased need for advanced methods to assess dependability and safety of the products. Especially considering that many products are safety-critical, where faults can have catastrophic consequences; think of components in modern vehicles, medical engineering devices, or control systems in nuclear reactor plants.

Testing is an important method to discover faults. A system is subjected to different sequences of input signals, and the generated output signals are compared to the expected output signals. Should a discrepancy be discovered between the actual outputs and the expected outputs, a fault has been discovered and must somehow be corrected. Knowledge about which input signals caused the unexpected outputs can then guide the correction work.

But testing cannot try all possible combinations of input signals, these are simply too many for this to be done within reasonable time. Thus, sequences of input signals must be chosen cleverly so that as much as possible of the system functionality is tested in a short time.

Model-based testing is a concept where from a model of the system under test, its expected behavior, and possibly the environment with which the system under test is to interact, such cleverly selected sequences of input signals can be calculated. This has shown to be beneficial both in a time and quality perspective, more faults are found faster, and has recently had a big industrial impact.

However, with the increasing complexity of the tested systems, also the sizes of the models increase. Here now enters a new problem, namely that the sizes of the models make test sequence calculations intractable with conventional methods, at least within reasonable time. Test generation becomes too complex for straightforward algorithms.

The COMBAT-project aims to combat this complexity issue by applying abstraction-based compositional methods to the problem of test calculations for complex systems. These types of methods exploit the fact that the models are typically given as a set of rather simple sub-models, which interact to create the full model. Compositional methods can then gradually build the full model, and at the same time apply abstractions to remove redundant detail. The result is then a compact model that can be used for quick generation of compact test cases.

Compositional methods have shown to very useful within other areas, such as calculation of supervisors for discrete event systems. Results from this research show that abstraction-based compositional methods can calculate supervisor for significantly larger system models than conventional means. The models and methods used for supervisor calculation has much in common with the models and methods used for model-based test generation.

Thus, the COMBAT-project aims to adapt the existing compositional methods so that these can be applied to model-based test generation. This will increase the applicability of model-based test generation so that more complex products can be engineered with greater confidence.

### Popular scientific description (Swedish)*

Komplexiteten hos ingenjörsutvecklade produkter ökar ständigt. Därmed behövs allt mer avancerade metoder för att säkerställa att produkterna fungerar som det är tänkt. Särskilt med tanke på att många av produkterna är säkerhetskritiska, oväntat beteende kan ha allvarliga konsekvenser; tänk på komponenter i fordon, styrsystem i kärnkraftverk eller medicintekniska system.

Testning är en viktig metod för att upptäcka felaktigheter. Ett system utsätts för olika sekvenser av insignaler, och de genererade utsignalerna jämförs med förväntade utsignaler. Skulle de faktiska utsignalerna skilja sig från de förväntade har ett fel upptäckts, och måste åtgärdas på något sätt. Kännedom om vilka insignaler som orsakade de oförväntade utsignalerna ger då kunskap om felet och hur det ska korrigeras.

Men testning kan inte pröva alla möjliga insignalskombinationer, de är helt enkelt för många för att detta ska kunna göras inom rimlig tid. Därför måste man välja insignalssekvenserna på ett smart sätt så att så mycket som möjligt av systemets funktion testas på kort tid.

Modell-baserad testning är ett konceptet där man utifrån en modell av det testade systemet, dess förväntade beteende, och eventuellt den omgivning systemet är tänkt att interagera med, beräknar just sådana smarta insignalssekvenser. Detta har visat sig fördelaktigt såväl ur tidsmässigt som kvalitetsmässigt perspektiv, och har på kort tid fått stort industriellt genomslag. Man hittar helt enkelt fler fel snabbare, med modell-baserade metoder.

Men, med ökande komplexitet hos de testade systemen, ökar också storleken på modellerna. Här kommer då ett nytt problem in, nämligen att storleken på modellerna gör dem svårhanterliga med konventionella metoder. Att beräkna testsekvenser blir i sig för komplicerat och tar för lång tid.

COMBAT-projektet syftar till att applicera abstraktions-baserade kompositionella metoder på problemet med beräkning av testsekvenser. Denna typ av metoder utnyttjar att modellerna typiskt är givna som en mängd ganska enkla sub-modeller som tillsammans utgör den stora komplexa modellen. Kompositionella metoder kan då gradvis bygga den fullständiga modellen, och samtidigt utnyttja abstraktionsmetoder för att plocka bort redundant information i modellen. Resultatet är en kompakt modell som nu kan användas för beräkning av testsekvenser.

Kompositionella metoder har visat sig väldigt användbara inom andra områden, till exempel vid beräkning av övervakare för händelsediskreta system. Resultat från forskning kring detta visar på att abstraktions-baserade kompositionella metoder kan beräkna övervakare för avsevärt större modeller än vad som tidigare varit möjligt. De modeller och metoder som används för övervakarberäkning har mycket gemensamt med de modeller och metoder som används för modell-baserad beräkning av testsekvenser.

COMBAT-projektet kommer därför att anpassa existerande abstraktions-baserad kompositionella metoder så att de kan användas för modell-baserad testning. Detta kommer att öka användbarheten av modell-baserad testning så att än mer komplexa produkter kan utvecklas med än större tillförlitlighet.

## Project period

### Number of project years*

4

### Calculated project time*

2016-01-01 - 2019-12-31

## Classifications

Select a minimum of one and a maximum of three SCB-codes in order of priority.

Select the SCB-code in three levels and then click the lower plus-button to save your selection.

**SCB-codes***

2. Teknik > 202. Elektroteknik och elektronik > 20207. Inbäddad systemteknik

2. Teknik > 202. Elektroteknik och elektronik > 20202. Reglerteknik

1. Naturvetenskap > 102. Data- och informationsvetenskap (Datateknik) > 10201. Datavetenskap (datalogi)

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Enter a minimum of three, and up to five, short keywords that describe your project.

**Keyword 1***

Testning

**Keyword 2***

Formella metoder

**Keyword 3***

Kompositionella metoder

**Keyword 4**

Säkerhetskritiska system

**Keyword 5**

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**Research plan**

## Ethical considerations

Specify any ethical issues that the project (or equivalent) raises, and describe how they will be addressed in your research. Also indicate the specific considerations that might be relevant to your application.

### Reporting of ethical considerations*

Projektet berör testning av implementerade tekniska system. Inga etiska övervägande är tillämpbara.

### The project includes handling of personal data

No

### The project includes animal experiments

No

### Account of experiments on humans

No

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## Research plan

## Purpose and aims

Testing engineering systems of modern complexity is so challenging that it asks for new techniques and further investigations. Therefore, **the purpose of the COMBAT project is to improve model-based test generation techniques. The aim is to use existing compositional abstraction-based methods to automatically derive test cases from both specification and environment models.**

Rigorous testing is a crucial part of the engineering development process to ensure correct functionality. This is especially important for safety-critical systems, such as typically man-made reactive systems like safety protocols for communication, autonomous vehicles, medical engineering devices, and embedded systems. It can be very difficult to design appropriate testing procedures for such systems, and large amounts of time and money have to be invested to test systems to a sufficient level.

Testing typically means to expose a SUT (*system under test*) to various input sequences, to observe the resulting outputs, and to assess whether this means that the system functions correctly or not. If an incorrect output is observed, then a failure has been detected, and the SUT must be corrected. If no failures are detected, then it is known that the system behaves correctly for the performed tests, and only those. In order to gain confidence in the correct functioning of the system as a whole, it is crucial how the input sequences for testing are chosen. Ideally, a system should be tested exhaustively by exposing it to all possible inputs, but this is in general not tractable due to the enormous number of possibilities, and due to time and monetary constraints.

Traditionally, the process of deriving tests tends to be unstructured, barely motivated in the details, not reproducible, not documented, and bound to the ingenuity of single engineers [A1]. A more systematic approach is known as model-based testing [A2][A3]. This method relies on models that describe the SUT, its intended behaviour (called the *specification*), and possibly the environment with which the SUT is to interact. Test cases are automatically generated from these models and then executed, manually or automatically, on the SUT. The specification may also describe the expected outcomes of the tests, and so these can be compared, manually or automatically, to the actual outcome produced by the SUT, and thus it can be determined whether tests pass or fail.

Model-based testing has shown to be beneficial both from a time and a quality perspective, and is getting wide-spread industrial acceptance; more errors are found faster, which increases the dependability of the engineered systems. However, as the complexity of the systems grows, so does the size and complexity of the models and the well-known *curse of dimensionality* arises in the form of the *state-space explosion problem*. Calculating test cases by conventional means get harder.

The COMBAT-project aims to combat this rising complexity problem by applying abstraction-based compositional methods for model-based test generation. This type of methods exploits the fact that the models are typically given in a modular form, consisting of a large number of small interacting sub-models, each typically rather simple in itself. By gradually building the big model, abstractions can be applied to the intermediate result to remove redundant details. The result is a compact model that can now be used for fast generation of compact test cases.

This approach borrows ideas from the supervisory control theory [A4], where from a model of a (physical) system, the plant, which describes the entire possible behaviour, and a model of the intended behaviour, the specification, a controlling agent, the

supervisor, can be automatically calculated such that the supervisor in closed-loop with the plant is guaranteed by construction to fulfill the specification. Abstraction-based compositional algorithms have been implemented within this context to automatically verify and synthesize supervisors, and have shown to be remarkably efficient [A5][A6]. The COMBAT project now aims to adjust and apply these techniques to model-based test generation, first for discrete event models (finite-state machines, and extended finite-state machines) defining logical behaviour, and as a second step to generalize the approach to hybrid models (cyber-physical systems) with both discrete and continuous behaviour.

**Survey of the field**

Model-based testing is a huge and very active field, particularly as software testing is concerned. [A7] defines software testing to consist "of the dynamic verification that a program provides expected behaviours on a finite set of test cases, suitably selected from the usually infinite execution domain".

[A2] lists the four main approaches known as model-based testing.

1. Generation of test input data from a domain model
2. Generation of test cases from an environment model
3. Generation of test cases with oracles from a behavioural model
4. Generation of test scripts from abstract tests

In the first approach, test generation uses knowledge about the domains of the input variables to cleverly select combinations that exhaust the test space without enumerating all possible combinations. The *pair-wise algorithm* is well-known in this respect. However, merely generating test inputs does not help in knowing whether a test passes or fails.

The second approach includes a model of the environment within which the SUT is meant to function. From the environment model it is possible to draw some conclusion about useful input sequences and generate tests from those. However, since the environment model does not include the behaviour of the SUT, it is not possible to define the expected output from the SUT. The role of the environment is merely to restrict the considered input sequences. The environment models typically employed in this case are statistical [A8].

An *oracle* is an agent, human or machine, that decides whether a program behaved correctly in a given test and thus assigns a verdict of passed or failed [A7]. Thus, in the third approach above, with oracle information generated from a behavioural model, it is possible to automatically check the actual output values to see if they are correct or not. Of course, this requires that the model includes the behaviour of the SUT, such as the relationship between its inputs and outputs.

The fourth approach above assumes that a very abstract description of a test case is given, such as a UML sequence diagram, and transforms that abstract test case into a low-level test script that is executable on the SUT. In this case, the model is the information about the structure and the interface of the SUT.

Generation of test cases from finite state machines is not new [A9][A10], and within the community of software testing this is an active field [A3]. [A1] describes several existing methods, referred to as the T-method, D-method, Wp-method, and W-method, respectively. Each of these has different coverability and test lengths [A11]. And all of them assume a monolithic model of the specification, and do not use any model of the environment.

Fully automated methods based on symbolic execution [A12] has for software shown capable of automatically generate test cases with very high coverability. The typical approach to software testing, though, is to test the software itself, in isolation from any environment that it may have been created to interact with. The [A7] definition of software testing does not mention the environment, and other works [A13][A14] take a similar view.

From a control perspective, however, the software implements some regulating functionality that through interaction is meant to affect the behaviour of an outside environment. This is the typical industrial case, where engineers develop software that, for instance, runs embedded in ECUs (*electronic control units*) to control different subsystems of a vehicle or medical device. Modern vehicles can include up to 80 such ECUs, controlling everything from doors, motors, power-train, steering etc. These units must be tested together with the subsystems that they control, in what is typically referred to as the *closed-loop*. Testing them in isolation may be partly beneficial, but of main importance is the closed-loop behaviour.

The typical approach to industrial development is nowadays model-based. Current engineering tools allow to include a model of the environment towards which the engineer develops the code to be embedded into the ECU, or similar. The code is not developed by writing source code, but by assembling higher-level components, code blocks, into structures that express signal flows and signal manipulation. Code generators are then used to transform the code block structures into executable code.

In this setting, testing takes place on several hierarchical levels. On the (in some sense) top level, referred to as MiL (*model in the loop*), testing is done "in the box"; both the SUT and the environment are models executing within the engineering tool. This is basically a behavioural simulation not running in real time. On the next lower hierarchical level, referred to as SiL (*software in the loop*), the SUT has been transformed into executable code but is still running in the box, interacting with the model of the environment. Testing on this level essentially tests that the code transformation works correctly. On the next lower level, PiL (*process in the loop*), the generated code runs embedded in its actual target system, but still interacting with the environment model in the computer. Testing on this level typically aims to find timing errors. On the lowest level, HiL (*hardware in the loop*), the SUT runs on the actual target system, while the environment is emulated in hardware. Such systems typically run in real-time.

At each transformational level, MiL, SiL, PiL, HiL, it is important that tests from higher levels can be applied also on the lower levels. Of course, testing on one level may reveal issues that need to be corrected on the higher level, and so there is an iterative process going up and down the hierarchies.

For one of the most used engineering tools Matlab Simulink/Stateflow, [A15][A16] present an approach to test generation that relies on transforming the MiL models into finite state machines and using either model checking or constraint programming techniques, to identify executable paths and to generate tests to invoke those paths. To invoke a certain path, sequences of other paths may have to be invoked first, and this is taken care of automatically. It is fair to say that the approach [A15][A16] is the current state-of-the-art in MiL test generation, but currently the approach is monolithic, which limits its application to rather small examples. Also, no abstraction methods are used, which further limits the approach. Researchers in the COMBAT

project have for a long time been collaborating with the [A15][A16] researchers, and this collaboration will continue within the COMBAT project.

**Project description**

The COMBAT project will use results from supervisory control theory [A4] to bring information about the environment of the SUT into the model-based testing process, and in combination with existing compositional abstraction-based methods will use this information to

- efficiently calculate test cases
- both negative and positive, with
- predefined coverage.

Models designed according to supervisory control theory are typically modular, i.e., they are made up of several interacting sub-models. Each sub-model in itself is typically rather simple, but their interaction gives rise to an overwhelming complexity. The explicit combination of the sub-models into a single monolithic model is not tractable for complex systems, since the number of states increases exponentially with the number of components. Retaining and exploiting the modular structure in a compositional way is a divide-and-conquer approach that has shown very promising results to avoid the construction of a monolithic model and obtain correct results nevertheless [A5][A6].

A supervisor [A4] is a logical control device that through interaction with the plant to be controlled dynamically restricts events from occurring, so as to keep the closed-loop controlled system of plant and supervisor within a desired specification that models the desired closed-loop behaviour. In this way, the supervisor is a safety device that prevents bad things from occurring, while at the same time allowing good things to occur.

Supervisory control theory describes the *synthesis* (automatic computation) of a minimally restrictive supervisor. Such a supervisor enables all permissible behaviour and disables all impermissible behaviour. The straightforward (and naive) way to generate test cases with full coverage from a supervisor and a model of the plant, would be to generate all sequences of events enabled by the supervisor and treat those as positive test cases; and to generate all sequences of events disabled by the supervisor but enabled by the plant, and treat those as negative test cases. However, this is in practice intractable, since the number of sequences of events in the worst case is exponential in the number of states. For systems of industrially interesting sizes, the number of states is huge.

Here is where the abstraction-based compositional methods come in. These methods exploit the use of mathematical abstractions [A5][A6][C1] essentially simplifications [A17] that preserve specific properties of interest. In the case of supervisor synthesis, the preserved property is called *synthesis equivalence* [A5], and it guarantees that the supervisor resulting from the compositional abstraction-based synthesis will exhibit the exact same closed-loop behaviour as would a supervisor synthesized from a monolithic model. The compositional supervisor will be modular and much more compact, though, than the monolithic supervisor (see examples in the Preliminary Results section), and this is where test generation benefits.

Note that though the implied context is development of control software that interact with a mechatronic system, and hence we speak of "controllers", "supervisors", and "plants", this is merely a convenient analogy; the approach is not limited to control

systems development but is applicable to many types of embedded systems, signal processing systems etc.

**Outset:** The outset of the COMBAT approach is that we are given

- a manually (or otherwise) designed *controller* as a "black box";
- a *plant* modelling a (physical) system, a.k.a. the *environment*;
- a *specification* describing the desired behaviour of the closed-loop system of environment and controller.

The task is now to calculate test cases that can determine if the controller indeed implements a closed-loop system according to the specification..

**Claim:** We can use the supervisory control theory [A4] for this. Using our compositional synthesis [A5], we can compute a supervisor from the models of plant and specification. This supervisor is least restrictive and therefore contains all control actions that need to be tested for. At the same time, the supervisor obtained with this method is modular, avoiding the state-space explosion. From this supervisor and the corresponding abstracted plant, compact test cases can be generated.

**Where do the models come from?** The specification is typically given in a semi-formal form, from which conversion to a formal model is not expected to be overwhelming. Building the plant model is more challenging, which might explain why this is seldom done. However, in many cases, like in model-based development, a plant model already exists in the form of a simulation model, and the formal model is extractable from this. Also, it should not be neglected that even if the models have to be built manually, this task gains insight into the systems, and as the models are modular, reuse is possible. [A2] describes a case where initial model building took much more time than actual testing, but building the models led to detection of flaws in the specification and after correcting those flaws most of the model could be kept with significant time savings on subsequent testing. This is similar to our own experience in relation to supervisor synthesis.

**What can we do better than others?** As mentioned above, the supervisory control theory permits the use of both plant and specification models, whereas model based test generation typically use only the specification. Compositional abstraction-based calculation of a supervisor from the plant and specification gives us a model of the entire intended and possible behaviour, which has several benefits. The supervisor is our oracle that permits to automatically conclude whether a test failed or passed. The supervisor is modular, which together with being abstracted, makes it possible to cope with large state spaces and produce compact test cases.

Existing model-based test generation methods are typically good at generating compact positive tests, i.e., tests that check whether the SUT can perform a particular operation or transition. This works because positive tests can be derived from the system requirements specification, without the need to consider the environment. But for reactive systems, it is at least equally important to consider negative tests, which check whether the SUT prevents certain harmful operations or transitions. If the requirements do not also specify undesired behaviour, a standard test generator basically has to guess, typically using some kind of randomization. With a supervisor encompassing the entire intended and possible behaviour of the closed-loop system, the parts of the plant that are not included in the supervisor represent faulty behaviour. This information makes it possible to generate negative tests without having to guess or randomize.

Within the taxonomy of ([A1] Fig 2), the COMBAT project is positioned within the input-output scope, with *untimed*, *deterministic*, *discrete event*/*hybrid* model characteristics, employing a *transition-based*, *operational* paradigm, with *structural* model coverage and *test case specifications* selection criteria. The test generation technology is *search-based algorithms*, and test execution is meant to be *off-line*. In addition, it is reasonable to believe that the test generation needs to rely on a number of *heuristics* that need to be researched and experimented with.

**Proposed Research and Timeline.** The project is intended to run for four years, and one PhD student (to be employed) working 100% in the project, is expected to graduate within these four years (effective time). Starting from the existing results and tools for compositional synthesis, the PhD student will develop methods for test case generation based on discrete event systems. He or she will investigate how synthesised supervisors can be used to obtain tests and test verdicts, and develop coverage criteria and algorithms to generate test cases based on a compositional model. After having solved the problem for discrete event systems (with no continuous behaviour), the PhD student will generalise the approach for hybrid systems (a.k.a. cyber-physical systems) with both discrete and continuous behaviour.

A rough plan the PhD student looks like:

- A rigorous literature survey of the field of model-based testing.
- Taking courses on software testing and supervisory control theory
- Developing methods for test generation from plant and specification, discrete models
- Implementing the developed methods in Supremica
- Licentiate thesis early 2018
- Developing and implementing methods for test generation for hybrid models
- PhD graduation early 2020

Apart from the licentiate and PhD theses, the following research outputs are expected:

- Conferences papers (WODES 2016, 2018, and 2020, CASE 2016-2019)
- Journal papers (~4, of which 1-2 before licentiate).

## Significance

"The increasing complexity in especially hybrid vehicles require faster and in the same time more reliable testing, without diverging manual work. Test case generation and formal methods is a promising and important way to the solution." (Jonn Lantz, PhD, Technical Expert, Electric Propulsion Systems, Volvo Car Corporation)

The last 30 years have seen a significant amount of research into model-based test generation, and [A1][A2] presents a detailed survey. [A18] gives a comprehensive overview of research in the field. Also, the surveys of [A19] and [A20] provide detailed overviews of the technical literature in the field of model-based testing. [A20] analyses 271 papers (out of 599 found related papers) and count more than 219 different model-based testing approaches that have been proposed, many of them with associated software tools. This abundance of approaches and tools shows that model-based testing is a very active field of research with significant interest both within academia and industry.

Furthermore, [A2] devotes the whole of Section 5 to cite research that evidence the cost-effectiveness of model-based testing relative non-model based approaches, its effectiveness of fault-detection, reuse, and quality in revealing faults. Needless to say, shipping defective products is a disaster for any company, but for companies that

deliver safety-critical products, such as the automotive industry, defective products not only harm the company but can also lead to injuries or even fatalities. High-quality testing is a crucial part of avoiding defects, and the COMBAT project aims to develop exactly this.

[A1] concludes by saying that "performance of test generation and the improvement of test generation techniques is also an area of on-going research, with the potential to further improve the scalability of current model-based testing approaches and tools." Herein lays the main significance of the COMBAT project.

### Preliminary Results

The mentioned compositional methods have been developed by the investigators behind the COMBAT project proposal [A5][A6]. The idea of compositional abstraction-based verification and synthesis is, given a set of components that through interaction represent the monolithic system, to calculate abstractions of those components and/or of suitably chosen compositions of them. This is then performed iteratively until one or more sub-compositions of practical manageability are achieved, whereupon the actual verification or synthesis can then be performed. Since the abstractions only remove redundant detail and preserve the properties of interest, the result will guarantee the same properties as would an approach that worked on the composed monolithic system.

Experimental results by [A5] and [A6] show that the compositional abstraction-based approach works remarkably well for many huge systems, where size is measured in the monolithic state-space. The experiments manage to verify and synthesize models of real industrial systems. The table below, adapted from [A5] shows reductions that can be achieved by compositional supervisor synthesis for finite automata. In the table, each row represents a well-known benchmark example [A6]. The **Num** column lists the number of components, and the **Size** column lists the approximate size of the monolithic state-space. The calculation time for the compositional abstraction-based algorithm is given in the **Seconds** column, and the **Supervisor** column lists the size of the largest supervisor component. In all these cases the monolithic supervisor would be of size comparable to the number listed in the **Size** column.

| System | Num | Size | Seconds | Supervisor |
|---|---|---|---|---|
| Automated guided vehicle | 16 | $2.6 \times 10^{7}$ | 0.25 | 2214 |
| Flexible manufacturing sys | 31 | $1.4 \times 10^{7}$ | 27.82 | 156454 |
| Central locking | 52 | $1.3 \times 10^{9}$ | 1.66 | 4 |
| Train test bed | 84 | $3.6 \times 10^{12}$ | 4.6 | 784 |

An important preliminary result is the test case generation for the PROFIsafe protocol for failsafe communication [A21], where first a model of the protocol was analysed with formal verification techniques, and several important properties proven. Then, based on the verified model, a set of test cases for the automatic execution of conformance tests were derived. Knowing that the model is correct, the conformance tests are now available to ascertain that different implementations of the protocol conform to the verified specification.

## International and national collaboration

The Automation research group at Chalmers has had and will further pursue collaboration with national and international researchers, among them the following:

- Professor Robi Malik, University of Waikato, New Zealand, has been the main source of interaction for previous VR-financed projects on compositional methods (2001-2154 and 2009-3786) [A5][A6][C1][C14][C16][C18][C20][C21][C25] [C27]-[C29], and will continue to be so for COMBAT. Professor Malik has experience with model-based test case generation for the PROFIsafe communication protocol [A21] and he is a colleague of Professor Mark Utting, author of a well-known textbook on model-based test generation [A2]. Professor Malik is also involved with developing Supremica [2][C25].
- Professor Ratnesh Kumar of the Department of Electrical & Computer Engineering and Computer Science, at Iowa State University, Iowa, USA, has for a long time been close collaborator with the Principle Investigator of the COMBAT project. Professor Kumar has recently developed methods for test generation from Matlab Simulink/Stateflow models by transforming the models to extended finite state machines [A15][A16][A22].
- The Formal Methods group at the Department of Computer Science and Engineering, at Chalmers. This collaboration has been on-going [A23] and is now gaining momentum.

The work of the COMBAT project will be presented at appropriate conferences, typically WODES2016, 2018, and 2020, and CASE annually. In addition, we aim for 1-2 journal papers annually. All publications from the COMBAT project will be available in full text from Chalmers Library, and thus also from SwePub. They will also be found in full text on the web site of the University of Waikato, New Zealand. So they will all be available in open access databases. The project results will be implemented in our software tool Supremica [2][C25], available for free download at www.supremica.org.

## Other participating researchers

The Automation group at Chalmers has had a long collaboration in compositional abstraction-based synthesis and verification. Recently, February 2015, the PhD-student Sahar Mohajerani obtained her PhD, and will now work as Testing and verification engineer at Volvo Active Safety. Sahar did her PhD partly financed (for three years) by a previous VR-financed project, 2009-3786. It is expected that the COMBAT-project will have some collaboration with her.

The work will be performed within the Automation Research Group at the Department of Signals and Systems, S2, Chalmers University of Technology. In 2012, S2 had 65 senior researchers, 63 employed PhD students and 8 technical and administrative staff. Income and expenses were roughly equal, ~150 MSEK.

The Automation group is part of the Division of Automatic Control, Automation and Mechatronics, which in 2012 had 21 senior researchers and 26 employed PhD students. The Automation group is internationally renowned for its work in formal methods for automation, and will host the 11$^{th}$ annual IEEE International Conference on Automation Science and Engineering, IEEE CASE 2015, in Göteborg (http://case2015.org/ ). The group managed to get a record number of submissions, 430 regular papers.

Professors Fabian and Åkesson are also involved with research with the Chalmers Area of Advance, Sustainable Production.

## References

[A1] Mark Utting, Alexander Pretschner and Bruno Legeard. A Taxonomy of Model-Based Testing, Software Testing, Verification, Testing and Reliability, 22:297–312, 2012.

[A2] Mark Utting and Bruno Legeard. Practical model-based testing : a tools approach. Morgan Kaufmann, 2010.

[A3] Justyna Zander, Ina Schieferdecker, Pieter J. Mosterman, Model-Based Testing for Embedded Systems. CRC Press 2011.

[A4] Peter J. Ramadge and W. Murray Wonham. *The control of discrete event systems*, Proceedings of the IEEE, 77(1):81-98, January 1989.

[A5] Sahar Mohajerani. *On Compositional Supervisor Approaches for Discrete Event Systems Verification and Synthesis*. PhD Thesis 3821, Department of Signals and Systems, Chalmers University of Technology, February 2015.

[A6] Hugo Flordal, *Compositional Approaches in Supervisory Control*, PhD Thesis 2542, Department of Signals and Systems, Chalmers University of Technology, Göteborg, Sweden, 2006.

[A7] P. Bourque and R.E. Fairley, eds., Guide to the Software Engineering Body of Knowledge, Version 3.0, IEEE Computer Society, 2014; www.swebok.org

[A8] Böhr, F., "Model Based Statistical Testing of Embedded Systems," Software Testing, Verification and Validation Workshops (ICSTW), 2011 IEEE Fourth International Conference on , vol., no., pp.18,25, 21-25 March 2011.

[A9] Tsun S. Chow. Testing Software Design Modeled by Finite-State Machines IEEE Transactions on Software Engineering, vol. SE-4, no. 3, May 1978.

[A10] David Lee, Mihalis Yannakakis. Principles and Methods of testing Finite State Machines - A Survey. Proc. IEEE, vol. 84, no. 8, August 1996.

[A11] Bo Yang and Hasan Ural, Protocol Conformance Test Generation using Multiple UIO Sequences with Overlapping, SIGCOMM Comput. Commun. Rev. 20, 4 (August 1990), 118-125.

[A12] Cadar, Cristian, Daniel Dunbar, and Dawson R. Engler. "KLEE: Unassisted and Automatic Generation of High-Coverage Tests for Complex Systems Programs." OSDI. Vol. 8. 2008.

[A13] Prowell, S.J., "JUMBL: a tool for model-based statistical testing," System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on , vol., no., pp.9 pp.,, 6-9 Jan. 2003.

[A14] Conformiq, 2015. http://www.conformiq.com/model-based-testing/system-models/

[A15] M. Li and R. Kumar, “Stateflow to Extended Finite Automata Translation”, 2011 IEEE International Computer Systems and Applications Conference, Munich,July 2011.

[A16] M. Li and R. Kumar, “Simulink/Stateflow Test Generation based on Extended Finite Automata”, 2012 IEEE Conference on Automation Science and Engineering, Seoul, Korea, August 2012.

[A17] Susanne Graf and Bernhard Steffen. *Compositional minimization of finite state systems*. Proceedings of the 2nd International Workshop on Computer Aided Verication, pages 186-196. Springer, 1991.

[A18] M. Broy, B. Jonsson, J.-P. Katoen, M. Leucker, A. Pretschner (Eds.), Model-Based Testing of Reactive Systems, no. 3472 in LNCS, SpringerVerlag, 2005.

[A19] Hierons R, Bogdanov K, Bowen J, Cleaveland R, Derrick J, Dick J, Gheorghe M, Harman M, Kapoor K, Krause P, L¨uttgen G, Simons A, Vilkomir S, Woodward M, Zedan H. *Using formal specifications to support testing*. ACM Computing Surveys 2009; 41(2):9:1–9:76.

[A20] Dias Neto AC, Subraman yan R, Vieira M, Travassos GH. A survey on model-based testing approaches: a systematic review. WEASELTec h '07: Proceedings of the 1st ACM International Workshop on Empirical Assessment of SW Engineering Languages and Technologies. ACM: New York, NY, U.S.A., 2007; 31–36.

[A21] R. Malik, R. Mühlfeld. A case study in verification of UML statecharts: the PROFIsafe protocol. Journal of Universal Computer Science, 9 (2), 138-151, 2003.

[A22] M. Li+ and R. Kumar,"Reduction of Automated Test Generation for Simulink/Stateflow to Reachability and its Novel Resolution", 2013 IEEE International Conference on Automation Science and Engineering, Madison, WI, 2013.

[A23] K Claessen, N Een, M Sheeran, N Sörensson, A Voronov, K Åkesson. *SAT-solving in practice, with a tutorial example from supervisory control*. Discrete Event Dynamic Systems 19 (4), 495-524, 2009.

## Interdisciplinarity

### My application is interdisciplinary

☐

An interdisciplinary research project is defined in this call for proposals as a project that can not be completed without knowledge, methods, terminology, data and researchers from more than one of the Swedish Research Councils subject areas; Medicine and health, Natural and engineering sciences, Humanities and social sciences and Educational sciences. If your research project is interdisciplinary according to this definition, you indicate and explain this here.

Click here for more information

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## Scientific report

### Scientific report/Account for scientific activities of previous project

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## Budget and research resources

### Project staff

Describe the staff that will be working in the project and the salary that is applied for in the project budget. Enter the full amount, not in thousands SEK.

Participating researchers that accept an invitation to participate in the application will be displayed automatically under Dedicated time for this project. Note that it will take a few minutes before the information is updated, and that it might be necessary for the project leader to close and reopen the form.

#### Dedicated time for this project

| | Role in the project | Name | Percent of full time |
|---|---|---|---|
| 1 | Applicant | Martin Fabian | 20 |
| 2 | Participating researcher | Knut Åkesson | 10 |
| 3 | Participating researcher | Robi Malik | 10 |

#### Salaries including social fees

| | Role in the project | Name | Percent of salary | 2016 | 2017 | 2018 | 2019 | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | Applicant | Martin Fabian | 20 | 268,000 | 277,000 | 287,000 | 297,000 | 1,129,000 |
| 2 | Participating researcher | Knut Åkesson | 10 | 107,000 | 111,000 | 114,000 | 118,000 | 450,000 |
| 3 | Participating researcher | PhD-student | 100 | 544,000 | 563,000 | 582,000 | 603,000 | 2,292,000 |
| | Total | | | 919,000 | 951,000 | 983,000 | 1,018,000 | 3,871,000 |

### Other costs

Describe the other project costs for which you apply from the Swedish Research Council. Enter the full amount, not in thousands SEK.

## Premises

| | Type of premises | 2016 | 2017 | 2018 | 2019 | Total |
|---|---|---|---|---|---|---|
| 1 | Kontor | 66,000 | 68,000 | 71,000 | 73,000 | 278,000 |
| | Total | 66,000 | 68,000 | 71,000 | 73,000 | 278,000 |

## Running Costs

| | Running Cost | Description | 2016 | 2017 | 2018 | 2019 | Total |
|---|---|---|---|---|---|---|---|
| 1 | Utrustning | Dator | 25,000 | | | | 25,000 |
| 2 | Konferenskostnader | Konferenser | 30,000 | 30,000 | 30,000 | 30,000 | 120,000 |
| 3 | Resekostnader | Resor | 40,000 | 40,000 | 40,000 | 40,000 | 160,000 |
| 4 | Litteratur och materel | Kontorsmateriel | 30,000 | 25,000 | 25,000 | 25,000 | 105,000 |
| 5 | IT | IT | 20,000 | 21,000 | 22,000 | 22,000 | 85,000 |
| | Total | | 145,000 | 116,000 | 117,000 | 117,000 | 495,000 |

## Depreciation costs

| | Depreciation cost | Description | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|

## Total project cost

Below you can see a summary of the costs in your budget, which are the costs that you apply for from the Swedish Research Council. Indirect costs are entered separately into the table.

Under Other costs you can enter which costs, aside from the ones you apply for from the Swedish Research Council, that the project includes. Add the full amounts, not in thousands of SEK.

The subtotal plus indirect costs are the total per year that you apply for.

### Total budget

| Specified costs | 2016 | 2017 | 2018 | 2019 | Total, applied | Other costs | Total cost |
|---|---|---|---|---|---|---|---|
| Salaries including social fees | 919,000 | 951,000 | 983,000 | 1,018,000 | 3,871,000 | | 3,871,000 |
| Running costs | 145,000 | 116,000 | 117,000 | 117,000 | 495,000 | | 495,000 |
| Depreciation costs | | | | | 0 | | 0 |
| Premises | 66,000 | 68,000 | 71,000 | 73,000 | 278,000 | | 278,000 |
| Subtotal | 1,130,000 | 1,135,000 | 1,171,000 | 1,208,000 | 4,644,000 | 0 | 4,644,000 |
| Indirect costs | 337,000 | 349,000 | 361,000 | 374,000 | 1,421,000 | | 1,421,000 |
| Total project cost | 1,467,000 | 1,484,000 | 1,532,000 | 1,582,000 | 6,065,000 | 0 | 6,065,000 |

## Explanation of the proposed budget

Briefly justify each proposed cost in the stated budget.

### Explanation of the proposed budget*

Pengar är sökta för en doktorand, inklusive handledning och lokaler, datorutrustning, resor etc. Driftskostnader inkluderar resekostnader, vilka innefatter besök hos Professor Robi Malik, vid University of Waikato, Nya Zeeland. Notera att vi sökt pengar för en doktorand 100% under fyra år. Detta avser effektiv tid, då en doktorandutbildning normalt omfattar 5 år, med ca 20% undervisning

## Other funding

Describe your other project funding for the project period (applied for or granted) aside from that which you apply for from the Swedish Research Council. Write the whole sum, not thousands of SEK.

### Other funding for this project

| Funder | Applicant/project leader | Type of grant | Reg no or equiv. | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|

## CV

**CV − Martin Fabian**

1. Higher education qualification
    - Master of Science Chemical Engineering, 1989, Chalmers University of Technology, Göteborg, Sweden
2. Degree of Doctor
    - Ph D, Control Engineering, 1995, Chalmers. Thesis entitled *On Object-Oriented Supervisory Control*, supervised by Professor Bengt Lennartson.
3. Postdoctoral positions
4. Qualification required for appointment as a docent
    - 2001
5. Present position
    - 2014, Full Professor in Automation at Chalmers, 30% research
6. Previous positions and periods of appointment
    - 2009, Professor in Automation, Chalmers
    - 2001, Associate Professor (docent) in Automation, Chalmers
    - 1995, Assistant Professor at the Control and Automation Laboratory, Chalmers
7. Interruption in research
    - 2000, four months parental leave
8. Supervision
    - Sahar Mohajerani, PhD, 2015
    - Patrik Bergagård, PhD, 2015
    - Julien Provost, post-doc at the Automation group, 2012-2013
    - Kristin Andersson, PhD 2009
    - Avenir Kobetski, PhD 2008
    - Johan Richardsson, PhD 2007 (industrial PhD student at Volvo Car)
    - Hugo Flordal, PhD 2006
    - Arash Vahidi, PhD 2004
    - Knut Åkesson, PhD 2002
9. Research Grants and Project Participations

- 2014-2017, VirtCom2 - Virtual preparation and commissioning of production systems including PLC logics, VINNOVA-FFI project.
- 2010-2015, Chalmers Area of Advance, Sustainable Production. Supported by VINNOVA, through the Wingquist Laboratory VINN Excellence Centre at Chalmers University of Technology.
- 2010-2012, Compositional Synthesis of Supervisors for Modular Discrete Event Systems, `Cossmodes`. Supported by the Swedish Research Council, VR 2009-3786. Main applicant and project leader.
- 2008-2012, Flexible Automation (FLEXA), EU-financed project managed by Volvo Aero, Trollhättan, Martin Fabian is Chalmers' representative in WP 5.
- 2003-2007, Virtual Verification of Product and Production Systems, supported by SSF/ProViking, co-applicant with Bengt Lennartson and vice project leader.

- 2002-2004, Development Verification and Implementation of Discrete Event Systems, Devides. Supported by the Swedish Research Council, VR 2001-2154. Main applicant and project leader.

## 10. Academic Merits

- 2014, co-author of the WODES 2014 Best Student Paper, see [C16].
- 2013, manuscript reviewer for the PhD thesis of Ms Salam Hajjar, "A Safe design method of embedded systems based on COTS", Department of Computer Science, INSA de Lyon (Institut National des Sciences Appliquées de Lyon), France.
- 2009, Faculty Opponent for Lenko Grigorov on his thesis *Conceptual design of discrete-event systems using templates*. Supervisor: Prof Karen Rudie, Queen's University, Kingston, Canada.
- 2009, Guest Editor for Journal on Discrete Event Dynamic Systems (Springer Netherlands) special issue on WODES'08
- 2008, the 9th Workshop on Discrete Event Systems, Chalmers, Editor-in-Chief for the review process
- 2007, "Supervisory Control Theory", course in the Ph.D program in Information Engineering at Politecnico di Milano, Italy (invited)
- 2007, Associate Editor for IEEE Trans. on Automation Science and Engineering
- 2006, Modeling, Control and Optimization of Discrete Event Systems (PV35), course within the national SSF-founded ProViking Graduate School.
- 2005, member of the grading committee for Niklas Een, PhD student at Computing Science, "SAT Based Model Checking", Professor Mary Sheeran was Niklas' examiner and supervisor.
- 2001, Control of Discrete Event Systems (CDES), PhD course for Chalmers PhD students, including students from Computing Science.

## 11. Conference Program Committees (selected)

- Program Chair at the 11th annual IEEE International Conference on Automation Science and Engineering (IEEE CASE 2015), Gothenburg, Sweden.
- Awards Chair at the 9th International Conference on Automation Science and Engineering (IEEE CASE 2013), Madison, Wisconsin, USA.
- 2012, the 11th International Workshop on Discrete Event Systems
- 2011, the 16th International Conference on Emerging Technologies and Factory Automation
- 2010, the 6th Conference on Automation Science and Engineering
- 2009, the 2009 IEEE Conference on Automation Science and Engineering
- 2009, the 2nd IFAC Workshop on Dependable Control of Discrete Systems
- 2008, the 9th Workshop on Discrete Event Systems, Chalmers, member of the organizing committee

## 12. Committee Memberships

- Member of IEEE SMC technical Committee on Discrete Event Systems
- Member of the SIS/TK 280 "Product and process data" committee
- Member of the IFAC TC 1.3 Technical Committee on Discrete Event and Hybrid Systems

# Curriculum Vitae: Knut Åkesson

Department of Signals and Systems
Division: Automatic Control, Automation and Mechatronics
Research Group: Automation

Chalmers University of Technology, Sweden
phone: + 46 31 772 3717
email: knut@chalmers.se

March 31, 2015

## Birthdate

June 1st, 1972.

## Family

Spouse Josefina Adebahr. Children Erik Adebahr (born 2008) and Axel Adebahr (born 2011)

## Degrees

- Honorary Docent in Automation (In Swedish: Oavlönad docent i automation), Department of Signals and Systems, Chalmers University of Technology, June 2009.
- Doctor of Philosophy in Control Engineering (In Swedish: Teknologie doktor), School of Electrical and Computer Engineering, Chalmers University of Technology, September 2002. Thesis title: *Methods and tools in supervisory control theory – Operator aspects, computational efficiency, and applications.* Supervisor Dr. Martin Fabian, co-supervisor Prof. Bo Egardt.
- Master of Science in Computer Science and Engineering (In Swedish: Civilingenjör i Datateknik), Lund Institute of Technology, March 1997. Thesis title: *On Security in Distributed Systems.*

## Academic Appointments

- Position as associate professor (In Swedish: docenttjänst). November 2009 – present. Department of Signals and Systems, Chalmers University of Technology.
- Position as assistant professor (In Swedish: forskarassistent) funded by the Swedish research council (Vetenskapsrådet). January 2003 – October 2009. Department of Signals and Systems, Chalmers University of Technology.

### Supervision of Ph.D. students (Main supervisor)

- Goran Čengić, Started August 2003. Co-supervised with Prof. Bengt Lennartson. Licentiate degree awarded November 2006. PhD degree awarded February 2009. In this case I was acting as the main supervisor from Goran started his research until he graduated. On paper Prof. Bengt Lennartson was the main supervisor because I was not formally appointed Docent.

- Oscar Ljungkrantz, Started October 2005. Co-supervised with Prof. Martin Fabian. Licentiate degree awarded April 2008. PhD degree awarded in October 2011.
- Alexey Voronov, Started August 2007. Co-supervised with Prof. Martin Fabian. Licentiate degree awarded May 2010. PhD degree awarded in January 2013.
- Zhennan Fei, Started September 2009. Co-supervised with Prof. Spyros Reveliotis at Georgia Institute of Techology, USA. Licentiate degree June 2012. PhD degree awarded May 2014.
- Amir Hossein Ebrahimi, Started January 2012. Licentiate degree expected, fall 2015.

I was also very actively involved in the supervison of Sajed Miremadi that graduated with the PhD degree in December 2012. In this case I was formally the co-supervisor with Prof. Bengt Lennartson as the main supervisor.

## Interruption in research

- On part-time parental leave in 2008 (from Sept). On part-time parental leave in Feb-Mar 2012, full-time Apr-Jun 2012.

### Tools and spin-offs

- 1999–: Initiator, main architect and developer of Supremica, a tool for analysis and design of discrete event supervisors. Supremica has functionality for synthesis and verification, graphical simulation, code generation, and execution of discrete event supervisors. Several researchers, mainly Martin Fabian, Arash Vahidi, Hugo Flordal and Robi Malik, have made important contributions.
  For more information see `http://www.supremica.org`.
- 2011–: CEO Confirmlogic AB. Co-founder of a research spin-off that sell a product configuration engine that are able to solve very large product configuration problems as well as supporting maintenance of large configuration rule sets.

### Professional activities

- Associate editor, IEEE Transaction on Automation Science and Engineering, January 2012 –. Member of the Conference Editorial Board of the IEEE International Conference on Robotics & Automation (ICRA) (2010-2012).

Member of program committee:

- *11th IEEE International Conference on Emerging Technologies and Factory Automation* (ETFA'06), Prague, Czech Republic, 2006. *The Sixth IEEE Conference on Industrial Informatics* (INDIN'08), Daejeon, Korea, 2008. *2008 IEEE Conference on Automation Science and Engineering* (IEEE CASE 2008), Washington DC, USA, 2008. *2009 IEEE Conference on Automation Science and Engineering* (IEEE CASE 2009), Bangalore, India, 2009. *10th International Workshop on Discrete Event Systems* (WODES'10), Berlin, Germany, 2010. *11th International Workshop on Discrete Event Systems* (WODES'12), Guadalajara, Mexico, 2012. *12th International Workshop on Discrete Event Systems* (WODES'14), Paris, France, 2014. *2010 IEEE Conference on Automation Science and Engineering* (IEEE CASE 2010). Program track chair (Foundations of Automation) for *2012 IEEE Conference on Automation Science and Engineering* (IEEE CASE 2012).

Member of organizing committee:

- Reglermötet 2004, Göteborg, Sweden, 2004. 9th International Workshop on Discrete Event Systems (WODES'08), Göteborg, Sweden, 2008. The eleventh annual IEEE International Conference on Automation Science and Engineering (IEEE CASE 2015), Göteborg, Sweden 2015.

## 5. CURRICULUM VITAE AND PUBLICATIONS

**PART 1**

| **1a. Personal details** | | | | | |
|---|---|---|---|---|---|
| **Full name** | *Title*<br>Dr | *First name*<br>Robi | *Second name(s)* | *Family name*<br>Malik | |
| **Present position** | Senior Lecturer | | | | |
| **Organisation/Employer** | The University of Waikato | | | | |
| **Contact address** | Private Bag 3105 | | | | |
| | Hamilton | | | Post code | 3240 |
| **Work telephone** | 07 838 4796 | | Mobile | | |
| **Email** | robi@waikato.ac.nz | | | | |
| **Personal website (if applicable)** | http://www.cs.waikato.ac.nz/~robi | | | | |

### 1b. Academic qualifications

*1998, Dr. rer. nat. (PhD), Computer Science, Universität Kaiserslautern, Germany.*
*1993, Diplom-Informatiker (MSc), Computer Science, Universität Kaiserslautern, Germany.*

### 1c. Professional positions held

*2009–present, Senior Lecturer, University of Waikato, Hamilton, New Zealand.*
*2003–2009, Lecturer, University of Waikato, Hamilton, New Zealand.*
*2002, Visiting Scientist, Konrad-Zuse-Zentrum für Informationstechnik, Berlin, Germany.*
*1998–2002, Engineer, Siemens Corporate Technology, Munich, Germany.*
*1995–1998, Teaching Assistant, Department of Computer Science, Universität Kaiserslautern, Germany.*
*1994–1995, Tutor, Department of Computer Science, Universität Kaiserslautern, Germany.*

### 1d. Present research/professional speciality

*Dr Robi Malik is an expert in compositional methods of model checking discrete event systems. These are methods that exploit the modelling structure of a system composed of many synchronised finite-state automata, in order to check critical properties more efficiently. His early results about incremental verification of safety properties, developed 2000–2002 at Siemens Corporate Technology, are still of interest and cited regularly today.*
*After joining the University of Waikato in 2003, Dr Robi Malik shifted his focus from safety properties to the more difficult problem of nonblocking verification. The discovery of conflict equivalence in 2004 became the foundation for most of his research since 2006. Partly in cooperation with Chalmers University of Technology in Göteborg, Sweden, he developed practical solutions to check very large systems for the nonblocking property, based on this theory. The results of the PhD thesis of Simon Ware, supervised by Dr Robi Malik, show how to compare and abstract systems with respect to conflict equivalence.*
*Presently, Dr Robi Malik is continuing research on compositional nonblocking verification and synthesis. He is co-supervising PhD student Sahar Mohajerani with Prof Martin Fabian at Chalmers University of Technology in Göteborg, Sweden, who is applying the techniques for compositional nonblocking verification to the problem of supervisor synthesis.*
*In addition, Dr Robi Malik is pursuing several other applications of compositional reasoning with discrete event systems. In collaboration with Prof José Cury at the Federal University*

*of Santa Catarina in Florianópolis, Brazil, and Prof Patrícia Pena at the Federal University of Minas Gerais in Belo Horizonte, Brazil, he has been working on methods for checking the observer property of discrete event systems and for abstraction of extended finite-state automata. In collaboration with Assoc Prof Ryan Leduc at McMaster University in Hamilton, Canada, he has developed methods for compositional verification of interface consistency properties of hierarchical discrete event system models and of co-observability of distributed systems.*
*Since 2005, Dr Robi Malik's group at the University of Waikato is involved in the development of the Supremica Software, which is jointly developed at the University of Waikato and at Chalmers University of Technology in Sweden. Supremica is used to design and analyse reactive control software modelled as finite-state machines or extended finite-state machines. Supremica is freely available for download at www.supremica.org, and currently is one of the best supervisor synthesis tools world-wide. It is used for teaching and research, at the University of Waikato, at Chalmers University of Technology, and at other universities.*

**1f. Professional distinctions and memberships (including honours, prizes, scholarships, boards or governance roles, etc)**

*2008–2017, Member of the IFAC Technical Committee 1.3 on Discrete Event and Hybrid Systems.*
*2008–2014, Member of the Scientific Program Committee for the Workshop on Discrete Event Systems (WODES 2008, 2010, 2012, and 2014).*
*2013–2015, Member of the Program Committee for the Formal Techniques for Safety-Critical Systems workshop (FTSCS 2013, 2014, and 2015).*
*2015, Associate editor for the 2015 IEEE International Conference on Automation Science and Engineering (CASE 2015).*
*2015, Member of the Scientific Program Committee for the 11th International IEEE/IFIP Workshop on Software Technologies for Future Embedded and Ubiquitous Systems (SEUS 2015)*
*2012, Member of the Scientific Program Committee for the 4th IFAC Conference on Analysis and Design of Hybrid Systems (ADHS'12).*
*2011, Member of the Technical Program Committee for the 9th IEEE/IFIP International Conference on Embedded and Ubiquitous Computing (EUC 2011).*
*2002–2007, Responsible for the "Tool development for microCharts" objective of the FRST contract UOWX0202 "Formal Methods and Data Mining".*
*2003, Invited presentation at the Siemens TS Summer School in Magdeburg, Germany, "Verification and Testing of UML Statecharts: the PROFIsafe Protocol".*
*1994–1995, Landesgraduiertenstipendium (PhD scholarship), Universität Kaiserslautern, Germany.*

## Publication list

## Martin Fabian – Publications

h-index: 19; i10-index: 41; citation source: Google Scholar

### 1. Five most cited articles

[1] Fabian, M; Hellgren, A. *PLC-based Implementation of Supervisory Control for Discrete Event Systems*. 37th IEEE Conference on Decision and Control (CDC'98), Tampa, Florida, USA, December 1998. Number of citations: 148

* [2] Åkesson, K.; Fabian, M.; Flordal, H.; Malik, R. S*upremica - An Integrated Environment for Verification, Synthesis and Simulation of Discrete Event Systems*. 8th Workshop on Discrete Event Systems (WODES'06), Ann Arbor, Michigan, USA, July 2006. Number of citations: 137

[3] Sköldstam, Markus; Åkesson, Knut; Fabian, Martin, *Modeling of Discrete Event Systems using Finite Automata With Variables*, 46th IEEE Conference on Decision and Control (CDC), New Orleans, Louisiana, USA, December 2007. Number of citations: 79

[4] Knut Åkesson, Hugo Flordal, Martin Fabian, *Exploiting Modularity for Synthesis and Verification of Supervisors*, Proceedings of the IFAC World Congress on Automatic Control, Barcelona, Spain, July 2002. Number of citations: 68

[5] Åkesson, K; Fabian, M; Flordal, H; Vahidi, A. *Supremica - A Tool for Verification and Synthesis of Discrete Event Supervisors*. 11th Mediterranean Conference on Control and Automation, Rhodos, Greece, 2003. Number of citations: 57

### 2. Peer-reviewed original articles 2007-2014

* [C1] Mohajerani, S., Malik, R., Fabian, M. *A Framework for Compositional Synthesis of Modular Nonblocking Supervisors*, Automatic Control, IEEE Transactions on, 59(1), pp 150-162, January 2014. Number of citations: 4

[C2] Lennartson, B., Basile, F., Miremadi, S., Fei, Z., Hosseini, M.N., Fabian, M., Åkesson, K. *Supervisory Control for State-Vector Transition Models—A Unified Approach*, Automation Science and Engineering, IEEE Transactions on, 11(1), pp 33-47, January 2014. Number of citations: 1

[C3] Patrik Bergagård and Martin Fabian, *Calculating Restart States for Systems Modeled by Operations Using Supervisory Control Theory*, Machines 2013, 1(3), 116-141. Number of citations: 2

[C4] Å Fasth, J Provost, M Fabian, J Stahre, B Lennartson. *From task allocation towards resource allocation when optimising assembly systems*, Procedia CIRP, vol 3, pp. 400-4005, December 2012. Number of citations: 1

[C5] Ljungkrantz, Oscar; Åkesson, Knut; Yuan, Chengyin; Fabian, Martin: *Towards Industrial Formal Specification of Programmable Safety Systems*, IEEE Transactions on Control Systems Technology, 20(6):1567-1574, November 2012. Number of citations: 5

[C6] Oscar Ljungkrantz, Knut Åkesson, Martin Fabian, Amir Hossein Ebrahimi. *An empirical study of control logic specifications for programmable logic controllers*, Empirical Software Engineering, (doi={10.1007/s10664-012-9232-x}) October 2012. Number of citations: -

[C7] Kristin Andersson; Bengt Lennartson; Petter Falkman; Martin Fabian. *Generation of restart states for manufacturing cell controllers*, Control Engineering Practice, 19(9):1014-1022, September 2011. Number of citations: 7

[C8] Bengt Lennartson; K. Bengtsson; C. Y. Yuan; Kristin Andersson; Martin Fabian; Petter Falkman; Knut Åkesson. *Sequence Planning for Integrated Product, Process and Automation Design*, IEEE Transactions on Automation Science and Engineering, 7(4):791-802, Oct 2010. Number of citations: 42

[C9] Kristin Andersson; Bengt Lennartson; Martin Fabian. *Restarting Manufacturing Systems; Restart States and Restartability*, IEEE Transactions on Automation Science and Engineering, 7(3):486-499, July 2010. Number of citations: 11

[C10] Oscar Ljungkrantz; Knut Åkesson; Martin Fabian; Chengyin Yuan. *Formal Specification and Verification of Industrial Control Logic Components*, IEEE Transactions on Automation Science and Engineering, 7(3)´:538-548, July 2010. Number of citations: 19

[C11] Kristin Andersson, Johan Richardsson, Bengt Lennartson and Martin Fabian. *Coordination of Operations by Relation Extraction for Manufacturing Cell Controllers*, IEEE Transactions on Control Systems Technology, 18(2):414-429, March 2010. Number of citations: 14

[C12] Avenir Kobetski, Martin Fabian. *Time-Optimal Coordination of Flexible Manufacturing Systems Using Deterministic Finite Automata and Mixed Integer Linear Programming*, Journal of Discrete Event Dynamic Systems, March 2009. Number of citations: 11

[C13] Flordal H., Fabian M., Akesson K., Spensieri D. *Automatic model generation and PLC-code implementation for interlocking policies in industrial robot cells*, Control Engineering Practice, 15 (11), pp.1416-1426, November 2007. Number of citations: 23

* [C14] Hugo Flordal, Robi Malik, Martin Fabian and Knut Åkesson, *Compositional Synthesis of Maximally Permissive Supervisors using Supervision Equivalence*, Journal of Discrete Event Dynamic Systems, August 2007. Number of citations: 49

### 3. Peer-reviewed conference contributions 2007-2014

[C15] Brian Bonafilia, Pontus Carlsson, Sebastian Nilsson, Martin Fabian. *Robust Manual Control of a Manufacturing System using Supervisory Control Theory*, 19th IFAC World Congress, Cape Town, South Africa, 24-29 August 2014. Number of citations: -

* [C16] Sahar Mohajerani; Robi Malik; Martin Fabian. *An Algorithm for Compositional Nonblocking Verification of Extended Finite-State Machines*. 12th IFAC-IEEE International Workshop on Discrete Event Systems (WODES) 2014, Paris, France, May 2014. Number of citations: -

[C17] Bengt Lennartson, Oskar Wigström, Martin Fabian, Francesco Basile. *Unified Model for Synthesis and Optimization of Discrete Event and Hybrid Systems*, 12th IFAC-IEEE International Workshop on Discrete Event Systems (WODES) 2014, Paris, France, May 2014. Number of citations: -

* [C18] Sahar Mohajerani; Robi Malik; Martin Fabian. *Compositional Nonblocking Verification for Extended Finite-State Automata Using Partial Unfolding*, IEEE International Conference on Automation Science and Engineering (CASE), Madison, Wisconsin, USA, 2013. Number of citations: 5

[C19] P. Bergagård, M. Fabian. *Derivation of placement transitions for offline calculation of restart states*, 18th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 2013. Number of citations: -

[C20] Sahar Mohajerani; Robi Malik; Martin Fabian. *An Algorithm for weak synthesis observation equivalence for compositional supervisor synthesis*, 11th Workshop on Discrete Event Systems (WODES 2012), Guadalajara, Mexico, Oct 2012. Number of citations: 3

[C21] S Mohajerani, R Malik, M Fabian. *Transition removal for compositional supervisor synthesis*. 8th IEEE International Conference on Automation Science and Engineering, Seoul, Korea, August 2012. Number of citations: -

[C22] P Bergagård, M Fabian. *Deadlock avoidance for multi product manufacturing systems modeled as sequences of operations*, 8th IEEE International Conference on Automation Science and Engineering, Seoul, Korea, August 2012. Number of citations: -

[C23] B Lennartson, S Miremadi, Z Fei, M Noori Hosseini, M Fabian, K Åkesson. *State-Vector Transition Model Applied to Supervisory Control*, 17th IEEE International Conference on Emerging Technologies & Factory Automation (ETFA), Krakow, Poland, September 2012. Number of citations: -

[C24] Julien Provost; Åsa Fasth; Johan Stahre; Bengt Lennartson; Martin Fabian. *Human operator and robot resource modeling for planning purposes in assembly systems*, 4th CIRP Conference on Assembly Technologies and Systems (CATS 2012), Ann Arbor, May 2012. Number of citations: 1

* [C25] Robi Malik, Martin Fabian, Knut Åkesson. *Modelling large-scale discrete-event systems using modules, aliases, and extended finite-state automata*. Proc. 18th IFAC World Congress (IFAC 2011), Milan, Italy, August - September 2011. Number of citations: 3

[C26] Patrik Magnusson; Nina Sundström; Kristofer Bengtsson; Bengt Lennartson; Petter Falkman; Martin Fabian. *Planning transport sequences for flexible manufacturing systems*. Proceedings of the 18th IFAC World Congress (IFAC 2011), Milan, Italy, August - September 2011. Number of citations: 8

[C27] Sahar Mohajerani; Robi Malik; Martin Fabian. *Nondeterminism Avoidance in Compositional Synthesis of Discrete Event Systems*. IEEE Conference on Automation Science and Engineering 2011, August 2011. Number of citations: 8

[C28] Sahar Mohajerani; Robi Malik; Simon Ware; Martin Fabian. *On the Use of Observation Equivalence in Synthesis Abstraction*, 3rd International Workshop on Dependable Control Of Discrete Systems (DCDS'11), Saarbrücken, Germany, June 2011. Number of citations: 9

[C29] Sahar Mohajerani; Robi Malik; Simon Ware; Martin Fabian. *Compositional Synthesis of Discrete Event Systems Using Synthesis Abstraction*, The 23rd Chinese Control and Decision Conference (CCDC 2011). Mianyang, China, 23-25 May, 2011. Number of citations: 7

[C30] Patrik Magnusson; Martin Fabian; Knut Åkesson. *Modular specification of forbidden states for supervisory control*, 10th International Workshop on Discrete Event Systems (WODES 2010), Berlin, 30 August - 1 September 2010. Number of citations: 1

* [C31] Sajed Miremadi; Knut Åkesson; Bengt Lennartson; Martin Fabian. *Supervisor Computation and Representation: A Case Study*, 10th International Workshop on Discrete Event Systems (WODES 2010), Berlin, 30 August - 1 September 2010. Number of citations: 5

[C32] Oscar Ljungkrantz; Knut Åkesson; Martin Fabian; Chengyin Yuan, *A formal specification language for PLC-based control logic*. 8th IEEE International

Conference on Industrial Informatics (INDIN 2010); Osaka; July 2010. Number of citations: 6

[C33] Kristin Andersson; Bengt Lennartson; Petter Falkman; Martin Fabian. *Generation of restart states for manufacturing systems with discarded workpieces*, IEEE Conference on Automation Science and Engineering (CASE 2009), Bangalore, India, August 2009. Number of citations: 1

[C34] Kristin Andersson; Bengt Lennartson; Martin Fabian. *Synthesis of Restart States for Manufacturing Cell Controllers*. 2nd IFAC Workshop on Dependable Control of Discrete Systems (DCDS'09), Bari, Italy, June 2009. Number of citations: 3

[C35] Oscar Ljungkrantz, Knut Åkesson, Martin Fabian. *Formal Specification and Verification of Components for Industrial Logic Control Programming*, 4th IEEE Conference on Automation Science and Engineering (CASE 2008), Washington, D.C., USA. August 23-26, 2008. Number of citations: 7

[C36] Avenir Kobetski, Martin Fabian. *Velocity Balancing in Flexible Manufacturing Systems*, 9th Workshop on Discrete Event Systems (WODES'08), Göteborg, Sweden, May 2008. Number of citations: 6

[C37] Sajed Miremadi, Knut Åkesson, Martin Fabian, Arash Vahidi, Bengt Lennartson. *Solving Two Supervisory Control Benchmark Problems Using Supremica*, 9th Workshop on Discrete Event Systems (WODES'08), Göteborg, Sweden, May 2008. Number of citations: 16

* [C38] Sköldstam, Markus; Åkesson, Knut; Fabian, Martin, *Modeling of Discrete Event Systems using Finite Automata With Variables*, 46th IEEE Conference on Decision and Control (CDC), New Orleans, Louisiana, USA, December 2007. Number of citations: 60

[C39] Kobetski, Avenir; Richardsson, Johan; Åkesson, Knut; Fabian, Martin, *Minimization of Expected Cycle Time in Manufacturing Cells with Uncontrollable Behavior*, 3rd IEEE International Conference on Automation Science and Engineering (CASE), Scottsdale, Arizona, USA, Sept. 2007. Number of citations: 2

[C40] Richardsson, Johan; Andersson, Kristin; Fabian, Martin, *Reliable Control of Complex Manufacturing Cells*, 2007 IEEE International Symposium on Assembly and Manufacturing (ISAM), Ann Arbor, Michigan, USA, July 2007. Number of citations: 1

### 4. Review articles, book chapters, books 2007-2014

[C41] Simon Ware, Robi Malik, Sahar Mohajerani, Martin Fabian. *Certainly Unsupervisable States*. In *Formal Techniques for Safety-Critical Systems*, Artho, Cyrille, Ölveczky, Peter Csaba (Eds.), Series on Communications in Computer and Information Science, Vol. 419, Springer, 2014.

[C42] Martin Fabian, Zhennan Fei, Sajed Miremadi, Bengt Lennartson, Knut Åkesson. *Supervisory Control of Manufacturing Systems using Extended Finite Automata*. In *Formal Methods in Manufacturing*, Javier Campos, Carla Seatzu, Xiaolan Xie (editors), Series on Industrial Information Technology, CRC Press/Taylor and Francis, 2014.

[C43] Oscar Ljungkrantz, Knut Åkesson and Martin Fabian. *Practice of Industrial Control Logic Programming using Library Components*. In *Programmable Logic Controller*, Luiz Affonso Guedes (editor), ISBN: 978-953-7619-63-3, InTech, DOI: 10.5772/7191. January, 2010.

## 5. Patents 2007-2014

US Patent number: 7809457, “Framework for automatic generation of sequence of operations”, Oct 2010.

## 6. Publicly available computer programs 2007-2014

*Supremica*, http://www.supremica.org is a computer tool for modeling and synthesizing supervisors. It is used in many courses on discrete event systems around the world (including Chalmers), as well as by international researchers. Supremica is a joint collaboration between the University of Waikato, Hamilton, New Zealand, and Chalmers, involving Professor Robi Malik from Waikato, and Knut Åkesson and Martin Fabian from Chalmers, plus PhD and Masters students from both universities. Supremica implements most of the algorithms developed in the research projects. See also [2] and [3], above. Noteworthy is the use of *Supremica* at ENS-Cachan, France, where more than 100 students each year use *Supremica* in a course on control of reactive systems. This course is given by Professor Jean-Marc Foure at LURPA, ENS-Cachan.

## 7. Popular-scientific articles/presentations 2007-2014

2014, Column in *Dagens Industri* supplement “Vår nya automationsindustri”, 2014-10-01, http://dagensindustri.se/Vara-Tidningar/Bilagor/

# Publications: Knut Åkesson

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31 mars 2015

List of publications until March 2015. Statistic according to Google scholar (2015-03-31), h-index 18, total number of citations 1113. Link to Google Scholar page with citation data for all publications: http://goo.gl/rQVNyJ.

## Peer-reviewed original articles

A-1 Zhennan Fei, Spyros Reveliotis, Sajed Miremadi and Knut Åkesson, A BDD-Based Approach for Designing Maximally Permissive Deadlock Avoidance Policies for Complex Resource Allocation Systems, IEEE Transaction on Automation Science and Engineering, Accepted for publication.

A-2 (*)Sajed Miremadi, Zhennan Fei, Knut Åkesson, Bengt Lennartson. Symbolic Supervisory Control of Timed Discrete Event Systems. IEEE Transactions on Control Systems Technology, vol. 23, pp. 584-597, 2015.

A-3 Zhennan Fei, Sajed Miremadi, Knut Åkesson, Bengt Lennartson. Efficient Symbolic Supervisor Synthesis for Extended Finite Automata. IEEE Transactions on Control Systems Technology, vol. 17, pp. 338-344, 2014.

A-4 Ljungkrantz, Oscar; Åkesson, Knut; Fabian, Martin; Amir Hossein Ebrahimi; An empirical study of control logic specification for programmable logic controllers; Empirical Software Engineering, June 2014, Volume 19, Issue 3, pp. 655-677.

A-5 (*)Sajed Miremadi, Zhennan Fei, Knut Åkesson, Bengt Lennartson. Symbolic Representation and Computation of Timed Discrete Event Systems. IEEE Transactions on Automation Science and Engineering, vol. 11, no. 1, pp. 6-19, 2014.

A-6 Bengt Lennartson, Francesco Basile, Sajed Miremadi, Zhennan Fei, Mona Noori Hosseini, Martin Fabian, Knut Åkesson. Supervisory Control for StateVector Transition ModelsA Unified Approach. IEEE Transactions on Automation Science and Engineering, vol. 11, no. 1, pp. 33-47, 2014.

A-7 Martin Fabian, Zhennan Fei, Sajed Miremadi, Bengt Lennartson and Knut Åkesson; Supervisory Control of Manufacturing Systems Using Extended Finite Automata; Formal Methods in Manufacturing, Javier Campos, Carla Seatzu, Xiaolan Xie (Editors). CRC Press 2014. pp. 295-314. 2014. Book chapter.

A-8 (*)Zhennan Fei, Sajed Miremadi, Knut Åkesson, Bengt Lennartson. Symbolic State-Space Exploration and Guard Generation in Supervisory Control Theory. Agents and Artificial Intelligence of Communications in Computer and Information Science, vol. 271, pp. 161-175, 2013. Book chapter.

A-9 Ljungkrantz, Oscar; Åkesson, Knut; Fabian, Martin; Yuan, Chengyin; Towards Industrial Formal Specification of Programmable Safety Systems; IEEE Transactions on Control Systems Technology, 2012, 20(6), pp. 1567-1574.

A-10 Bengtsson Kristofer, Patrik Bergagard, Carl Thorstensson, Bengt Lennartson, Knut Akesson, Chengyin Yuan, Sajed Miremadi, Petter Falkman; Sequence planning using multiple and coordinated sequences of operations. IEEE Transactions on Automation Science and Engineering, 9(2).pp. 308-319, 2012.

A-11 Miremadi, Sajed; Lennartson, Bengt; Åkesson, Knut; A BDD-Based Approach for Modeling Plant and Supervisor by Extended Finite Automata. IEEE Transactions on Control Systems Technology, 2012, 20(6), pp. 1421-1435.

A-12 Miremadi, Sajed; Åkesson, Knut; Lennartson, Bengt; Symbolic Computation of Reduced Guards in Supervisory Control; IEEE Transactions on Automation Science and Engineering. 8 (4), pp. 754 - 765. 2011.

A-13 (*) Ouedraogo, Lucien; Kumar, Ratnesh; Malik, Robi; Åkesson, Knut; Nonblocking and Safe Control of Discrete-Event Systems Modeled as Extended Finite Automata; IEEE Transactions on Automation Science and Engineering. 8 (3), pp. 560 - 569, 2011.

A-14 Lennartson, Bengt; Bengtsson, Kristofer; Chengyin Yuan; Andersson, Kristin; Fabian, Martin; Falkman, Petter; Åkesson, Knut; Sequence Planning for Integrated Product, Process and Automation Design. IEEE Transactions on Automation Science and Engineering. 7 (4), pp. 791 - 802, 2010.

A-15 Čengić, Goran; Åkesson, Knut; On Formal Analysis of IEC 61499 Applications, Part A: Modeling; IEEE Transactions on Industrial Informatics, 6 (2), pp. 136 – 144. 2010.

A-16 Čengić, Goran; Åkesson, Knut; On Formal Analysis of IEC 61499 Applications, Part B: Execution Semantics; IEEE Transactions on Industrial Informatics. 6 (2), pp. 145 – 154. 2010.

A-17 Ljungkrantz, Oscar; Åkesson, Knut; Fabian, Martin; Yuan, Chengyin; Formal Specification and Verification of Industrial Control Logic Components; IEEE Transactions on Automation Science and Engineering. 7 (3), pp. 538 – 548, 2010.

A-18 Claessen, Koen; Een, Niklas; Sheeran, Mary; Sörensson, Niklas; Voronov, Alexey; Åkesson, Knut: SAT-Solving in Practice, with a Tutorial Example from Supervisory Control. Discrete Event Dynamic Systems, 19 (4) pp. 495–524. 2009.

A-19 (*) Flordal, Hugo; Malik, Robi; Fabian, Martin; Åkesson, Knut: Compositional Synthesis of Maximally Permissive Supervisors Using Supervision Equivalence. Discrete Event Dynamic Systems, 17 (4) pp. 475–504. 2007.

A-20 Flordal, Hugo; Fabian, Martin; Åkesson, Knut; Spensieri, D.: Automatic model generation and PLC-code implementation for interlocking policies in industrial robot cells. Control Engineering Practice, 15 (11) pp. 1416–1426. 2007.

A-21 Michael Tittus and Knut Åkesson, Petri Net Models in Batch Control, Mathematical and Computer Modelling of Dynamical Systems, 5(2), pp. 113-132, 1999.

## Peer-reviewed conference contributions

B-1 A Symbolic Approach for Maximally Permissive Deadlock Avoidance in Complex Resource Allocation Systems. Fei, Zhennan, Reveliotis, Spyros. A. Åkesson Knut. 12th International Workshop on Discrete Event Systems (WODES), Paris; 2014.

B-2 Ebrahimi, Amir; Johansson, Pierre;Bengtsson, Kristofer;Åkesson, Knut. (2014). Managing product and production variety - A language workbench approach, Procedia CIRP. 338-344.

B-3 Yun Yixiao, Gu Y.H, Provost Julien, Åkesson Knut:Multi-View Hand Tracking using Epipolar Geometry-Based Consistent Labeling for an Industrial Application. Seventh ACM/IEEE International Conference on Distributed Smart Cameras (ICDSC 2013), 2013.

B-4 Provost Julien, Hossein Ebrahimi Amir, Åkesson Knut, Online support for shop-floor operators using body movements tracking, 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems, 2013. pp. 102-109.

B-5 Fei, Zhennan. ; Miremadi, Sajed; Åkesson, Knut; Lennartson, Bengt. A Symbolic Approach to Large-Scale Discrete Event Systems Modeled as Finite Automata with Variables, 2012 IEEE Conference on Automation Science and Engineering (CASE). pp. 502 - 507, 2012.

B-6 Lennartson, Bengt; Miremadi, Sajed; Fei, Zhennan;Noori Hosseini, Mona; Fabian, Martin; Åkesson, Knut. State-Vector Transition Model Applied to Supervisory Control, 17th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), pp. 1-8, 2012.

B-7 Miremadi, Sajed; Fei, Zhennan; Åkesson, Knut; Lennartson, Bengt; Symbolic Computation of Nonblocking Control Function for Timed Discrete Event Systems, 51st IEEE Conference on Decision and Control. pp. 7352-7359, 2012.

B-8 Tidstam, Anna; Bligård, Lars-Ola; Åkesson, Knut; Voronov, Alexey; Ekstedt, Fredrik ; Malmqvist, Johan; Development of Industrial Visualization Tools for Validation of Vehicle Configuration Rules, Proceedings of 9th International Symposium on Tools and Methods of Competitive Engineering, Karlsruhe, Germany. pp. 305-318, 2012.

B-9 Fei, Zhennan; Åkesson, Knut; Lennartson, Bengt: Symbolic reachability computation using the disjunctive partitioning technique in Supervisory Control Theory. 2011 IEEE International Conference on Robotics and Automation (ICRA), pp. 4364 - 4369. 2011.

B-10 Fei, Zhennan; Miremadi, Sajed; Åkesson, Knut: Modeling sequential resource allocation systems using Extended Finite Automata. 2011 IEEE Conference on Automation Science and Engineering (CASE), pp. 444 - 449. 2011.

B-11 Fei, Zhennan; Miremadi, Sajed; Åkesson, Knut; Lennartson, Bengt: Efficient Symbolic Supervisory Synthesis and Guard Generation: Evaluating partitioning techniques for the state-space exploration. ICAART 2011 - Proceedings of the 3rd International Conference on Agents and Artificial Intelligence, pp. 106-115. 2011.

B-12 Voronov, Alexey; Åkesson, Knut; Ekstedt, Fredrik: Enumeration of valid partial configurations. Proceedings of Workshop on Configuration, IJCAI 2011. pp. 25-31. 2011.

B-13 Bengtsson, Kristofer; Torstensson, Carl; Lennartson, Bengt; Åkesson, Knut; Yuan, Chengyin; Miremadi, Sajed; Falkman, Petter: Relations Identification and Visualization for Sequence Planning and Automation Design. In Proc. IEEE Conference on Automation Science and Engineering, Toronto, pp. 841 - 848. 2010.

B-14 Magnusson, Patrik; Fabian, Martin; Åkesson, Knut: Modular specification of forbidden states for supervisory control. 10th International Workshop on Discrete Event Systems (WODES), Berlin; 10 (1). 2010.

B-15 Ljungkrantz, Oscar; Åkesson, Knut; Fabian, Martin; Yuan, Chengyin: A Formal Specification Language for PLC-based Control Logic. 8th IEEE International Conference On Industrial Informatics, pp. 1067 - 1072, 2010.

B-16 Voronov, Alexey; Åkesson, Knut: Verification of Process Operations Using Model Checking. CASE 2009. IEEE International Conference on Automation Science and Engineering, pp. 415-420. 2009.

B-17 Čengić, Goran; Åkesson, Knut: A Control Software Development Method Using IEC 61499 Function Blocks, Simulation and Formal Verification. Proceedings of the 17th IFAC World Congress, pp. 22-27. 2008.

B-18 Čengić, Goran; Åkesson, Knut: Definition of the Execution Model Used in the Fuber IEC 61499 Runtime Environment. Proceedings of the 6th IEEE International Conference on Industrial Informatics, pp. 301-306. 2008.

B-19 Ljungkrantz, Oscar; Åkesson, Knut; Fabian, Martin: Formal Specification and Verification of Components for Industrial Logic Control Programming. Proceedings of the 4th IEEE Conference on Automation Science and Engineering, pp. 935-940. 2008.

B-20 Miremadi, Sajed; Åkesson, Knut; Lennartson, Bengt: Extraction and Representation of a Supervisor Using Guards in Extended Finite Automata. 9th International Workshop on Discrete Event Systems, pp. 193-199. 2008.

B-21 Voronov, Alexey; Åkesson, Knut: Supervisory Control using Satisfiability Solvers. Discrete Event Systems, 2008. WODES 2008. 9th International Workshop on, pp. 81-86. 2008.

B-22 Alenljung, Tord; Sköldstam, Markus; Lennartson, Bengt; Åkesson, Knut: PLC-based Implementation of Process Observation and Fault Detection for Discrete Event Systems. IEEE International Conference on Automation Science and Engineering, pp. 207-212. 2007.

B-23 Kobetski, Avenir; Richardsson, Johan; Åkesson, Knut; Fabian, Martin: Minimization of Expected Cycle Time in Manufacturing Cells with Uncontrollable Behavior. IEEE Conference on Automation Science and Engineering, 2007.

B-24 Ljungkrantz, Oscar; Åkesson, Knut; Richardsson, Johan; Andersson, Kristin: Implementing a Control System Framework for Automatic Generation of Manufacturing Cell Controllers. Proceedings of the 2007 IEEE International Conference on Robotics and Automation, 2007.

B-25 Ljungkrantz, Oscar; Åkesson, Knut: A Study of Industrial Logic Control Programming Using Library Components. Proceedings of the 3rd Annual IEEE Conference on Automation Science and Engineering, 2007.

B-26 Sköldstam, Markus; Åkesson, Knut; Fabian, Martin: Modeling of Discrete Event Systems using Automata With Variables. Proceedings of the 46th IEEE Conference on Decision and Control, pp. 3387-3392. 2007.

B-27 Åkesson, Knut; Sköldstam, Markus: Towards a Framework for Integrated Supervisory and Logic Control. 1St IFAC Workshop on Dependable Control of Discrete Systems, pp. 83-88. 2007.

B-28 Martin Byröd, Bengt Lennartson, Arash Vahidi, Knut Åkesson. Efficient Reachability Analysis on Modular Discrete-Event Systems using Binary Decision Diagrams. Proceeding of the 8th Workshop on Discrete Event Systems (WODES'06), Ann Arbor, MI, USA, 2006.

B-29 Knut Åkesson, Martin Fabian, Hugo Flordal, Robi Malik. Supremica - An Integrated Environment for Verification, Synthesis and Simulation of Discrete Event Systems. Proceeding of the 8th Workshop on Discrete Event Systems (WODES'06), Ann Arbor, MI, USA.

B-30 Goran Čengić, Oscar Ljungkrantz, Knut Åkesson. Formal Modeling of Function Block Applications Running in IEC 61499 Execution Runtime. Proceedings of the 2006 IEEE International Conference on Emerging Technology and Factory Automation, Prague, Czech Republic, 2006.

B-31 Goran Čengić, Oscar Ljungkrantz, Knut Åkesson. A Framework for Component Based Distributed Control Software Development Using IEC 61499. Proceedings of the 2006 IEEE International Conference on Emerging Technology and Factory Automation, Prague, Czech Republic, 2006.

B-32 Hugo Flordal, Domenico Spensieri, Knut Åkesson, Martin Fabian. Supervision of Multiple Industrial Robots - Optimal and Collision Free Work Cycles. Proceedings of the IEEE Conference on Control Applications, Taipei, Taiwan, 2004.

B-33 Hugo Flordal, Martin Fabian, Knut Åkesson, Anders Hellgren. Controllability Revisited: A Generalization for the Modular Approach. Proceedings of the 11th IFAC Symposium of Information Control Problems in Manufacturing, Salvador, Brazil, 2004.

B-34 Hugo Flordal, Martin Fabian, Knut Åkesson. Automatic Implementation And Veri- fication Of Coordinating PLC-Code For Robot Cells. Proceedings of the 11th IFAC Symposium of Information Control Problems in Manufacturing, Salvador, Brazil, 2004.

B-35 Knut Åkesson, Hybrid Computer-Human Supervision of Flexible Manufacturing Systems, Proceedings of the 8th IFAC Symposium on Automated Systems based on Human Skill and Knowledge, Gothenburg, Sept. 2003.

B-36 Knut Åkesson, Martin Fabian, Hugo Flordal, Arash Vahidi. Supremica – A Tool for Verification and Synthesis of Discrete Event Supervisors. Proc. of the 11th IEEE Mediterranean Conference on Control and Automation, Rhodos, Greece, 2003.

B-37 Knut Åkesson, Sachin Jain and Placid Ferreira. Hybrid Computer-Human Supervision of Discrete Event Systems, IEEE International Conference on Robotics and Automation. Washington DC, USA, 2002.

B-38 Knut Åkesson, Hugo Flordal and Martin Fabian. Exploiting Modularity for Synthesis and Verification of Supervisors, IFAC World Congress on Automatic Control. Barcelona, Spain, 2002.

B-39 Knut Åkesson, Martin Fabian and Arash Vahidi. Coordination of Batches in Flexible Production – alternative resources and alternative operations, IEEE American Control Conference. Chicago, USA, 2000.

B-40 Knut Åkesson and Martin Fabian. Implementing Supervisory Control for Chemical Batch Processes. IEEE International Conference on Control Applications. Hawaii, USA, 1999.

B-41 Michael Tittus and Knut Åkesson. Deadlock Avoidance in Batch Processes. IFAC World Congress on Automatic Control. Beijing, China, 1999.

B-42 Knut Åkesson and Michael Tittus. Modular Control for Avoiding Deadlock in Batch Processes. World Batch Forum. Baltimore, USA. 1998.

B-43 Michael Tittus and Knut Åkesson. Modular Supervisors for Deadlock Avoidance in Batch Processes. Proc. of Systems Man and Cybernetics. San Diego, USA, 1998.

B-44 Michael Tittus and Knut Åkesson. Discrete Event Models in Batch Control. Proc. of 2nd MATHMOD. Vienna, Austria. 1997.

## Patents

1. US Patent. US7809457 B2, Framework for automatic generation of sequence of operations. Chengyin Yuan, Fangming Gu, Stephan R. Biller, Magnus Johansson, Mikael Kjellgren, Richard C. Immers, Chieh-yi Jerry Yen, Bengt Erik Lennartson, Martin Fabian, Knut Åkesson, Petter Falkman.

## Computer tools

- Initiator, main architect and developer of Supremica, a tool for analysis and design of discrete event supervisors. Supremica has functionality for synthesis and verification, graphical simulation, code generation, and execution of discrete event supervisors. Several researchers, mainly Martin Fabian, Arash Vahidi, Hugo Flordal and Robi Malik, have made important contributions.
  For more information see `http://www.supremica.org`.
- Founder and CEO of Confirmlogic AB that develops the software for configuration rule management and analysis. This software is used by industrial customers.

## Five most cited papers

1. (*) Åkesson, Knut; Fabian, Martin; Flordal, Hugo; Malik, Robi: Supremica - An Integrated Environment for Verification, Synthesis and Simulation of Discrete Event Systems. Proceeding of the 8th Workshop on Discrete Event Systems (WODES'06), Ann Arbor, MI, USA, pp. 384-385, 2006. *Number of citations: 137.*

2. (*) Skoldstam, Markus; Åkesson, Knut; Fabian, Martin: Modeling of discrete event systems using finite automata with variables. 46th IEEE Conference on Decision and Control, 2007, pp. 3387-3392. *Number of citations: 79.*

3. (*) Åkesson, Knut; Flordal, Hugo; Fabian, Martin: Exploiting Modularity for Synthesis and Verification of Supervisors. Proceedings of the IFAC World Congress on Automatic Control, Barcelona, Spain, 2002. *Number of citations: 68.*

4. Čengić, Goran; Ljungkrantz, Oscar; Åkesson, Knut: Formal Modeling of Function Block Applications Running in IEC 61499 Execution Runtime. Proceedings of the 2006 IEEE International Conference on Emerging Technology and Factory Automation, Prague, Czech Republic, 2006. *Number of citations: 66.*

5. Åkesson, Knut; Fabian, Martin; Flordal, Hugo; Vahidi, Arash: Supremica - A Tool for Verification and Synthesis of Discrete Event Supervisors. Proc. of the 11th Mediterranean Conference on Control and Automation, Rhodos, Greece, 2003. *Number of citations: 57.*

## **2a. Research publications and dissemination** - Robi Malik

### Peer reviewed journal articles


[1] Marcelo Teixeira, Robi Malik, José E. R. Cury, and Max H. de Queiroz. Supervisory control of DES with extended finite-state machines and variable abstraction. *IEEE Transactions on Automatic Control*, 60(1):118–129, January 2015.

[2] Simon Ware and Robi Malik. Progressive events in supervisory control and compositional verification. *Control Theory and Technology*, 12(3):217–229, August 2014.

[3] Simon Ware and Robi Malik. An algorithm to test the conflict preorder. *Science of Computer Programming*, 89(A):23–40, September 2014.

[4] Sahar Mohajerani, Robi Malik, and Martin Fabian. A framework for compositional synthesis of modular nonblocking supervisors. *IEEE Transactions on Automatic Control*, 59(1):150–162, January 2014.

[5] Robi Malik and Ryan Leduc. Hierarchical modelling of manufacturing systems using discrete event systems and the conflict preorder. *Discrete Event Dynamic Systems: Theory and Applications*, May 2014.

[6] Robi Malik and Ryan Leduc. Compositional nonblocking verification using generalised nonblocking abstractions. *IEEE Transactions on Automatic Control*, 58(8):1–13, August 2013.

[7] Simon Ware and Robi Malik. Conflict-preserving abstraction of discrete event systems using annotated automata. *Discrete Event Dynamic Systems: Theory and Applications*, 22(4):451–477, 2012.

[8] Lucien Ouedraogo, Ratnesh Kumar, Robi Malik, and Knut Åkesson. Nonblocking and safe control of discrete-event systems modeled as extended finite automata. *IEEE Transactions on Automation Science and Engineering*, 8(3):560–569, July 2011.

[9] Hugo Flordal and Robi Malik. Compositional verification in supervisory control. *SIAM Journal of Control and Optimization*, 48(3):1914–1938, 2009.

[10] Hugo Flordal, Robi Malik, Martin Fabian, and Knut Åkesson. Compositional synthesis of maximally permissive supervisors using supervision equivalence. *Discrete Event Dynamic Systems: Theory and Applications*, 17(4):475–504, 2007.

[11] Robi Malik, David Streader, and Steve Reeves. Conflicts and fair testing. *International Journal of Foundations of Computer Science*, 17(4):797–813, 2006.

[12] Bertil A. Brandin, Robi Malik, and Petra Malik. Incremental verification and synthesis of discrete-event systems guided by counter-examples. *IEEE Transactions on Control Systems Technology*, 12(3):387–401, May 2004.

[13] R. Malik and R. Mühlfeld. A case study in verification of UML statecharts: the PROFIsafe protocol. *Journal of Universal Computer Science*, 9(2):138–151, February 2003.


### Peer reviewed books, book chapters, books edited


[1] P. Dietrich, R. Malik, W. M. Wonham, and B. A. Brandin. Implementation considerations in supervisory control. In B. Caillaud, P. Darondeau, L. Lavagno, and X. Xie, editors, *Synthesis and Control of Discrete Event Systems*, pages 185–201, Dordrecht, the Netherlands, 2002. Kluwer Academic Publishers.


### Refereed conference proceedings


[1] Simon Ware and Robi Malik. Supervisory control with progressive events. In *Proceedings of the 11th IEEE International Conference on Control and Automation, ICCA 2014*, pages 1461–1466, Taichung, Taiwan, June 2014. IEEE.

[2] Sahar Mohajerani, Robi Malik, and Martin Fabian. An algorithm for compositional nonblocking verification of extended finite-state machines. In *Proceedings of the 12th International Workshop on Discrete Event Systems, WODES'14*, pages 376–382, Paris, France, May 2014.

[3] Huailiang Liu, Ryan Leduc, Robi Malik, and S. Laurie Ricker. Incremental verification of co-observability in discrete-event systems. In *2014 American Control Conference*, pages 5446–5452, Portland, OR, USA, June 2014.

[4] Simon Ware, Robi Malik, Sahar Mohajerani, and Martin Fabian. Certainly unsupervisable states. In *Proceedings of the 2nd International Workshop on Formal Techniques for Safety-Critical Systems, FTSCS 2013*, pages 3–18, Queenstown, New Zealand, 2013.

[5] Marcelo Teixeira, Robi Malik, José E. R. Cury, and Max H. de Queiroz. Variable abstraction and approximations in supervisory control synthesis. In *2013 American Control Conference*, pages 120–125, Washington, DC, USA, June 2013.

[6] Colin Pilbrow and Robi Malik. Compositional nonblocking verification with always enabled events and selfloop-only events. In *Proceedings of the 2nd International Workshop on Formal Techniques for Safety-Critical Systems, FTSCS 2013*, pages 147–162, Queenstown, New Zealand, 2013.

[7] Sahar Mohajerani, Robi Malik, and Martin Fabian. Compositional nonblocking verification for extended finite-state automata using partial unfolding. In *Proceedings of the 9th International Conference on Automation Science and Engineering, CASE 2013*, pages 942–947, Madison, WI, USA, August 2013.

[8] Sahar Mohajerani, Robi Malik, and Martin Fabian. Transition removal for compositional supervisor synthesis. In *Proceedings of the 8th International Conference on Automation Science and Engineering, CASE 2012*, pages 690–695, Seoul, South Korea, August 2012.

[9] Sahar Mohajerani, Robi Malik, and Martin Fabian. An algorithm for weak synthesis observation equivalence for compositional supervisor synthesis. In *Proceedings of the 11th International Workshop on Discrete Event Systems, WODES'12*, pages 239–244, Guadalajara, Mexico, October 2012. IFAC.

[10] Robi Malik and Ryan Leduc. Hierarchical interface-based supervisory control using the conflict preorder. In *Proceedings of the 11th International Workshop on Discrete Event Systems, WODES'12*, pages 163–168, Guadalajara, Mexico, October 2012. IFAC.

[11] H. J. Bravo, A. E. C. da Cunha, P. N. Pena, R. Malik, and J. E. R. Cury. Generalised verification of the observer property in discrete event systems. In *Proceedings of the 11th International Workshop on Discrete Event Systems, WODES'12*, pages 337–342, Guadalajara, Mexico, October 2012. IFAC.

[12] Simon Ware and Robi Malik. A state-based characterisation of the conflict preorder. In *Proceedings of the 10th International Workshop on the Foundations of Coordination Languages and Software Architectures, FOCLASA 2011*, pages 34–48, Aachen, Germany, 2011.

[13] Simon Ware and Robi Malik. A process-algebraic semantics for generalised nonblocking. In *Proceedings of CATS 2011—Computing: The Australasian Theory Symposium*, pages 75–84, Perth, Australia, 2011.

[14] Sahar Mohajerani, Robi Malik, Simon Ware, and Martin Fabian. On the use of observation equivalence in synthesis abstraction. In *Proceedings of the 3rd IFAC Workshop on Dependable Control of Discrete Systems, DCDS 2011*, pages 84–89, Saarbrücken, Germany, 2011.

[15] Sahar Mohajerani, Robi Malik, Simon Ware, and Martin Fabian. Compositional synthesis of discrete event systems using synthesis abstraction. In *Proceedings of the 23rd Chinese Control and Decision Conference, CCDC 2011*, pages 1549–1554, Mi-

anyang, China, 2011.

[16] Sahar Mohajerani, Robi Malik, and Martin Fabian. Nondeterminism avoidance in compositional synthesis of discrete event systems. In *Proceedings of the 7th International Conference on Automation Science and Engineering, CASE 2011*, pages 19–24, Trieste, Italy, 2011.

[17] Robi Malik, Martin Fabian, and Knut Åkesson. Modelling large-scale discrete-event systems using modules, aliases, and extended finite-state automata. In *Proceedings of the 18th IFAC World Congress*, pages 7000–7005, Milan, Italy, 2011.

[18] Simon Ware and Robi Malik. Compositional nonblocking verification using annotated automata. In *Proceedings of the 10th International Workshop on Discrete Event Systems, WODES'10*, pages 374–379, Berlin, Germany, 2010.

[19] P. N. Pena, J. E. R. Cury, R. Malik, and S. Lafortune. Efficient computation of observer projections using OP-verifiers. In *Proceedings of the 10th International Workshop on Discrete Event Systems, WODES'10*, pages 416–421, Berlin, Germany, 2010.

[20] Lucien Ouedraogo, Ratnesh Kumar, Robi Malik, and Knut Åkesson. Symbolic approach to nonblocking and safe control of extended finite automata. In *Proceedings of the 6th International Conference on Automation Science and Engineering, CASE 2010*, pages 471–476, Toronto, ON, Canada, 2010.

[21] Ryan Leduc and Robi Malik. A compositional approach for verifying hierarchical interface-based supervisory control. In *Proceedings of the 10th International Workshop on Discrete Event Systems, WODES'10*, pages 114–120, Berlin, Germany, 2010.

[22] Annika Hinze, Judy Bowen, Yuting Wang, and Robi Malik. Model-driven GUI & interaction design using emulation. In *Proceedings of the 2nd ACM SIGHI Symposium on Engineering Interactive Computing Systems, EICS'10*, pages 273–278, Berlin, Germany, 2010.

[23] Robi Malik and Ryan Leduc. A compositional approach for verifying generalised nonblocking. In *Proceedings of the 7th IEEE International Conference on Control and Automation, ICCA'09*, pages 448–453, Christchurch, New Zealand, December 2009.

[24] Simon Ware and Robi Malik. The use of language projection for compositional verification of discrete event systems. In *Proceedings of the 9th International Workshop on Discrete Event Systems, WODES'08*, pages 322–327, Göteborg, Sweden, May 2008. IEEE.

[25] Robi Malik and Ryan Leduc. Generalised nonblocking. In *Proceedings of the 9th International Workshop on Discrete Event Systems, WODES'08*, pages 340–345, Göteborg, Sweden, May 2008. IEEE.

[26] Robi Malik and Hugo Flordal. Yet another approach to compositional synthesis of discrete event systems. In *Proceedings of the 9th International Workshop on Discrete Event Systems, WODES'08*, pages 16–21, Göteborg, Sweden, May 2008. IEEE.

[27] Robi Malik, Hugo Flordal, and Patrícia N. Pena. Conflicts and projections. In *Proceedings of the 1st IFAC Workshop on Dependable Control of Discrete Systems, DCDS '07*, pages 63–68, Paris, France, June 2007.

[28] Petra Malik, Robi Malik, David Streader, and Steve Reeves. Modular synthesis of discrete controllers. In *Proceedings of the 12th IEEE International Conference on Engineering of Complex Computer Systems, ICECCS'07*, pages 25–34, Auckland, New Zealand, 2007.

[29] Annika Hinze, Petra Malik, and Robi Malik. Interaction design for a mobile context-aware system using discrete event modelling. In *Proceedings of the 29th Australasian Computer Science Conference, ACSC'06*, pages 257–266, Hobart, Australia, 2006. Australian Computer Society.

[30] Hugo Flordal and Robi Malik. Supervision equivalence. In *Proceedings of the 8th International Workshop on Discrete Event Systems, WODES'06*, pages 155–160, Ann

Arbor, MI, USA, July 2006. IEEE.

[31] Hugo Flordal and Robi Malik. Modular nonblocking verification using conflict equivalence. In *Proceedings of the 8th International Workshop on Discrete Event Systems, WODES'06*, pages 100–106, Ann Arbor, MI, USA, July 2006. IEEE.

[32] Knut Åkesson, Martin Fabian, Hugo Flordal, and Robi Malik. Supremica—an integrated environment for verification, synthesis and simulation of discrete event systems. In *Proceedings of the 8th International Workshop on Discrete Event Systems, WODES'06*, pages 384–385, Ann Arbor, MI, USA, July 2006. IEEE.

[33] Robi Malik, David Streader, and Steve Reeves. Fair testing revisited: A process-algebraic characterisation of conflicts. In Farn Wang, editor, *Proceedings of the 2nd International Symposium on Automated Technology for Verification and Analysis, ATVA 2004*, volume 3299 of *LNCS*, pages 120–134, Taipei, Taiwan, October–November 2004. Springer.

[34] Robi Malik. On the set of certain conflicts of a given language. In *Proceedings of the 7th International Workshop on Discrete Event Systems, WODES'04*, pages 277–282, Reims, France, September 2004. IFAC.

[35] R. Malik and R. Mühlfeld. A case study in verification of UML statecharts: the PROFIsafe protocol. In *Proceedings of the 5th Workshop on Tools for System Design and Verification, FM-TOOLS 2002*, pages 89–93, 2002.

[36] Rami Debouk, Robi Malik, and Bertil Brandin. A modular architecture for diagnosis of discrete event systems. In *Proceedings of the 41st IEEE Conference on Decision and Control, CDC'02*, pages 417–422, December 2002.

[37] B. A. Brandin, R. Malik, and P. Dietrich. Incremental system verification and synthesis of minimally restrictive behaviours. In *2000 American Control Conference*, pages 4056–4061, Chicago, IL, USA, 2000.

[38] Robi Malik. Automated deduction of finite-state control programs for reactive systems. In Claude Kirchner and Hélène Kirchner, editors, *Proceedings of the 15th International Conference on Automated Deduction, CADE'98*, volume 1421 of *LNCS*, pages 302–316, Lindau, Germany, July 1998. Springer.

## Patents

[] **Robi Malik** and Martin Witte. Method of reducing finite controlling automata and corresponding computer-readable medium. Germany, Patent No: EP1202141B1, 2007.

**CV**

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| **Name:**Martin Fabian | **Doctorial degree:** 1995-12-20 |
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## Research education

**Dissertation title (swe)**

**Dissertation title (en)**

On Object-Oriented Supervisory Control

| Organisation | Unit | Supervisor |
|---|---|---|
| Chalmers tekniska högskola, Sweden<br>Sweden - Higher education Institutes | 3206 - Reglerteknik, automation och mekatronik | Bengt Lennartson |

| Subject doctors degree | ISSN/ISBN-number | Date doctoral exam |
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## Research education

**Dissertation title (swe)**

**Dissertation title (en)**

Methods and tools in supervisory control theory - Operator aspects, computational efficiency, and applications

| Organisation | Unit | Supervisor |
|---|---|---|
| Chalmers tekniska högskola, Sweden<br>Sweden - Higher education Institutes | 3206 - Reglerteknik, automation och mekatronik | Martin Fabian |
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| **Name:**Robi Malik | **Doctorial degree:** 1997-12-12 |
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## Research education

**Dissertation title (swe)**

**Dissertation title (en)**

Automatic Synthesis of Discrete Controllers from Logic Specifications

| Organisation | Unit | Supervisor |
|---|---|---|
| University of Kaiserslautern, Germany<br>Not Sweden - Higher Education institutes | Department of Computer Science | Otto Mayer |

| Subject doctors degree | ISSN/ISBN-number | Date doctoral exam |
|---|---|---|
| 10201. Datavetenskap (datalogi) | 3-8265-3383-6 | 1997-12-12 |

## Publications

| | |
|---|---|
| **Name:**Martin Fabian | **Doctorial degree:** 1995-12-20 |
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| **Gender:** Male | **Employer:** Chalmers tekniska högskola |

Fabian, Martin has not added any publications to the application.

## Publications

| | |
|---|---|
| **Name:** Knut Åkesson | **Doctorial degree:** 2002-10-18 |
| **Birthdate:** 19720601 | **Academic title:** Docent |
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Åkesson, Knut has not added any publications to the application.

## Publications

| | |
|---|---|
| **Name:**Robi Malik | **Doctorial degree:** 1997-12-12 |
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| **Gender:** Male | **Employer:** n/a |

Malik, Robi has not added any publications to the application.

## Register

### Terms and conditions

The application must be signed by the applicant as well as the authorised representative of the administrating organisation. The representative is normally the department head of the institution where the research is to be conducted, but may in some instances be e.g. the vice-chancellor. This is specified in the call for proposals.

The signature*from the applicant*confirms that:

- the information in the application is correct and according to the instructions form the Swedish Research Council
- any additional professional activities or commercial ties have been reported to the administrating organisation, and that no conflicts have arisen that would conflict with good research practice
- that the necessary permits and approvals are in place at the start of the project e.g. regarding ethical review.

The signature *from the administrating organisation* confirms that:

- the research, employment and equipment indicated will be accommodated in the institution during the time, and to the extent, described in the application
- the institution approves the cost-estimate in the application
- the research is conducted according to Swedish legislation.

The above-mentioned points must have been discussed between the parties before the representative of the administrating organisation approves and signs the application.

*Project out lines are not signed by the administrating organisation. The administrating organisation only sign the application if the project outline is accepted for step two.*

*Applications with an organisation as applicant is automatically signed when the application is registered.*