PROJECT PERIODIC REPORT

Grant Agreement number: 214755

Project acronym: QUASIMODO

Project title: Quantitative System Properties in Model-Driven-Design of Embedded Systems

Funding Scheme: STREP

Date of latest version of Annex I against which the assessment will be made: 15 Oct. 2007

Report Version: v (30 March. 2009)

Periodic report: **1st X** **2nd ☐** **3rd ☐** **4th ☐**

Period covered: **from January 1 2008** **to December 31 2008**

Name, title and organisation of the scientific representative of the project's coordinator[1]:

Professor Kim G. Larsen, Aalborg University, Denmark

Tel: +45 99 40 88 93

Fax: +45 99 40 97 98

E-mail: kgl@cs.aau.dk

Associate Professor Brian Nielsen, Aalborg University, Denmark

Tel: +45 99 40 88 83

Fax: +45 99 40 97 98

E-mail: bnielsen@cs.aau.dk

Project website[2] address: http://www.quasimodo.aau.dk/

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the grant agreement

[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm ; logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Declaration by the scientific representative of the project coordinator[1]

I, as scientific representative of the coordinator[1] of this project and in line with the obligations as stated in Article II.2.3 of the Grant Agreement declare that:

- The attached periodic report represents an accurate description of the work carried out in this project for this reporting period;
- The project (tick as appropriate):

  ☐ has fully achieved its objectives and technical goals for the period;

  X has achieved most of its objectives and technical goals for the period with relatively minor deviations[3];

  ☐ has failed to achieve critical objectives and/or is not at all on schedule[4].

- The public website is up to date, if applicable.
- To my best knowledge, the financial statements which are being submitted as part of this report are in line with the actual work carried out and are consistent with the report on the resources used for the project (section 3.6) and if applicable with the certificate on financial statement.
- All beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs, have declared to have verified their legal status. Any changes have been reported under section 5 (Project Management) in accordance with Article II.3.f of the Grant Agreement.

3 If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

4 If either of these boxes is ticked, the report should reflect these and any remedial actions taken.

Name of scientific representative of the Coordinator[1]: Kim G. Larsen & Brian Nielsen .....

Date: ...../ ...../ .....

Signature of scientific representative of the Coordinator[1]: .....

Table of Content

1. Publishable summary

This section should be of suitable quality to enable direct publication by the Commission. Please ensure that it is set out and formatted so that it can be printed as a stand-alone paper document not exceeding four pages. It shall also reflect the website of the project (if applicable).

Please include a summary description of the project objectives, a description of the work performed since the beginning of the project, a description of the main results achieved so far, the expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far). You should update this publishable summary at the end of each reporting period.

Please include also, as appropriate, diagrams or photographs illustrating and promoting the work of the project, the project logo and relevant contact details.

The address of the project public website should also be indicated, if applicable.

The objective of the Quasimodo project is to develop theory, techniques and tool components for handling quantitative constraints in model-driven development of real-time embedded systems. These real-time, hybrid and stochastic constraints involve the resources that a system may use (computation resources, power consumption, memory usage, communication bandwidth, costs, etc.), assumptions about the environment in which it operates (arrival rates, hybrid behaviour), and requirements on the services that the system has to provide (timing constraints, QoS, availability, fault tolerance, etc.).

More specifically, the project aims at:

1. Improving the modelling of diverse quantitative aspects of embedded systems.
2. Providing a wide range of powerful techniques for analysing models with quantitative information and for establishing abstraction relations between them.
3. Generating predictable code from quantitative models.
4. Improving the overall quality of testing by using suitable quantitative models as the basis for generating sound and correct test cases.
5. Applying the techniques to real-life case-studies and disseminating the results to industry.

By enabling early and automated analysis, design, and test of embedded systems with quantitative constraints, the results of Quasimodo will increase the competitiveness of European embedded systems industry and will help establish Europe as a leader in design of complex embedded systems.

Significant progress have been have been made during year 1. Our industrial partners have proposed four challenging case studies:

1. the Accumulator Charge Controller (provided by HYDAC),
2. the self-balancing scooter (provided by CHESS),

3. a Wireless Sensor Network (provided by CHESS), and
4. the attitude and orbit control software for the satellites Hershel and Planck (provided by TERMA).

During the first year we have identified a number of formalisms for specifying and modelling quantitative information. The starting point for these extensions is (timed) automata theory or Markov Decision Processes. Significant work has been made on formalisms and decision problems concerning resources, including work on Markov reward models as well as priced (or weighted) timed automata. Work on probabilistic extensions of timed automata has been made, including work on priced probabilistic timed automata integrating general quantitative costs with time and probabilities.. In the pursuit of impact on defacto industrial design notations, extensions and support for UML State-chart with stochastic and timing information have been provided.

Major progress has been made on (decidability of) model checking, equivalence and preorder checking for discrete time Markov chains, probabilistic timed automata as well as continuous timed Markov chains. In particular, efficient algorithmic methods based on abstraction/refinement with counter-example guidance (CEGAR) have been provided.

Significant amount of work has been made on (decidability of) *robust analysis* of timed automata, i.e. analysis that take into account the possibility of drifting clocks or perturbations in the timing of actions. This work includes efficient symbolic algorithmic implementations of robust reachability checking within the verification tool UPPAAL. Also, initial work on probabilistic interpretation of robust has been made.

Substantial progress has been made on model-checking controllability properties. We have shown how to synthesise winning strategies for timed games with imperfect information (partial observability), and implemented this in the UPPAAL-Tiga branch. Already this technique has been applied to the HYDAC Accumulator Charge Controller industrial case study, and resulted in synthesis of a near optimal correct, safe and robust controller that is 30-40% better than the existing one in terms of energy consumption.

Foundation for timed testing theory has been established with a various timed extensions of the classical *ioco*-testing for untimed systems.

Although the work progressed more slowly on design notations, substantial progress has been made on development of individual tools as well as experiments and plans for integrating tool components of the project with commercial and external tools. Overall, we have made significant scientific progress and find the project in overall good shape.

http://www.quasimodo.aau.dk/

Contact information:
Cooordinator: Kim G. Larsen (kgl@cs.aau.dk)
Co-Coord.: Brian Nielsen (bnielsen@cs.aau.dk)

Quantitative System Properties in Model-Driven-Design of Embedded Systems

2. Project objectives for the period

Please provide an overview of the project objectives for the reporting period in question, as included in Annex I of the Grant Agreement. These objectives are required so that this report is a stand-alone document.

Please include a summary of the recommendations from the previous reviews (if any) and indicate how these have been taken into account.

The overall first year objective is to consolidate the project definition and the quantitative modelling formalisms to be used during the project. This objective includes describing the industrial case studies that drives the Quasimodo research, and laying down the theoretical foundation consisting of a suitable set of quantitative modelling formalisms with precise semantics in terms on quantitative labelled transition systems and formal refinement/abstraction relations.

Also a first iteration of our research loop - developing theory, implementing in tools, and applying to case studies - for selected formalisms should be carried out.

The objectives are detailed through the description of milestones M1, M2 and M3.

Milestone M1 is project start verified by a kick-off meeting. Milestone M2 requires M2.1) a precise descriptions of case studies, M2.2) a plan for tool components and their integration in industrial tool chain.

Milestone M3 is to be verified through the availability of M3.1) a semantic foundation of quantitative models in terms of labelled transition systems including semantics of composition of models, refinements between models, M3.2) a formal definition of conformance and robustness between quantitative models and implementations, M3.3) first models of case studies, and M3.4) quantitative extensions identified by the needs of case studies.

Additional goals are to develop theory and tools for model checking of real-time probabilistic models (Task 2.1 D3.1) and model checking of controllability properties (Task 3.3 D3.3).

Reaching these objectives will give a very good foundation for the future work focusing on algorithms for analysis, synthesis and testing, their implementations in tools and applications to case studies.

The next section details how we have reached these objectives. Section 3.6 gives a summary comparing with the milestones and these objectives.

3. Work progress and achievements during the period

Please provide a concise overview of the progress of the work in line with the structure of Annex I of the Grant Agreement.

For each work package *-- except project management, which will be reported in section 3.5-- please provide the following information:*

- *A summary of progress towards objectives and details for each task;*
- *Highlight clearly significant results;*
- *If applicable, explain the reasons for deviations from Annex I and their impact on other tasks as well as on available resources and planning;*
- *If applicable, explain the reasons for failing to achieve critical objectives and/or not being on schedule and explain the impact on other tasks as well as on available resources and planning (the explanations should be coherent with the declaration by the project coordinator) ;*
- *a statement on the use of resources, in particular highlighting and explaining deviations between actual and planned person-months per work package and per beneficiary in Annex 1 (Description of Work)*
- *If applicable, propose corrective actions.*

3.1 *WP1 – Modelling and Specification*

The work on **T1.1 (Model Process Improvement)** is mainly projected for year 2 of the project, with ESI/RU as the leading partner. We have several very interesting case studies available that may serve as a starting point for our research. Within the Octopus project, for instance, ESI/RU this year constructed 138 interrelated UPPAAL models of the datapath of an Oce copier machine. Work on modelling the Zeroconf protocol by ESI/RU led to more than 50 interrelated UPPAAL models. Finally, as part of a course on operating systems, approximately 100 UPPAAL models have been constructed of various concurrency problems. Often, a slight improvement in one model, requires one to make a similar change 20 other models. Based on a classification of the various relationships between models, we want to come with a proposal for improved (tool support for) model management. In addition, we intend to work on an improved UPPAAL tutorial, with special emphasis on guidance of the modelling process.

In **T1.2 (Modelling of Quantitative System Aspects),** we have worked on the four different topics mentioned in the *Description of Work*, stochastic component-based modelling, probabilistic timed modelling, stochastic hybrid modelling, and resources modelling. The most significant results are:

1. We propose the Arcade approach for Architectural Dependability Evaluation. This work links existing ideas from concurrency theory and probabilistic systems to the area of dependability evaluation, opening up a new rich class of potential applications.
2. We have established a link between AADL (the architecture analysis and design language of the Society of Automotive Engineers) and the world of probabilistic automata and model checking.
3. We have shown that using an integral semantics probabilistic and expected reachability properties are preserved for Probabilistic Timed Automata (PTA) with closed, diagonal-free clock constraints. This allows checking a considerable set of interesting properties by first applying the integer semantics, resulting in a purely probabilistic model, and then using existing and proven probabilistic model checkers. We have developed a tool that automatically translates MODEST models – if corresponding to PTA – to input models for the PRISM probabilistic model checker (and other tools) using the integral representation of time.
4. We have done initial work on extending probabilistic automata with continuous behavior and safety verification of such probabilistic hybrid automata
5. We have studied and settled (decidability) a number of problems for Priced Timed Automata (pTA) including optimal infinite runs using mean pay-off or discounting metrics, model-checking as well as Pareto-optimal reachability for pTA with multiple costs.
6. In line with the HYDAC case study, a new line of natural decision and optimization problems have been identified in the setting of Priced Timed Automata with both negative and positive cost(-rates) on locations and transitions. (Un)decidability has been settled in certain settings but a large number of problems remain open.
7. For the model of Priced Probabilistic Timed Automata (PPTA) we provide an algorithm for cost-bounded probabilistic reachability analysis for PPTA, and define the conditions on which the problem is (un)decidable.

Our work on Arcade and AADL also fits within **T1.3 (Design Notations and Tools).** In addition, task T1.3 is targeting Statecharts, since this design notation is widely used for embedded software design. The main significant results that we obtained here is a translation of a subset of UML State-chart to timed automata and a transplation of extended UML State-charts to Markov decision problems in combination with a supporting tool.

With the adjustment of the consortium we are currently considering retargeting our activities towards Simulink and Stateflow, the latter being the State-charts dialect of Mathworks. This will require considerable additional work throughout the runtime of the project. Therefore, the delivery of the final version of D1.2 is proposed to be delayed to month 24.

3.2 *WP2 – Analysis*

In **T2.1 (State space representation and model checking**) the main focus has been to consider a model with multiple quantitative aspects, viz. continuous time (as in timed automata), costs, and probabilities. For improvements to the analysis of pure timed automata new heuristic search algorithms have been implemented in the tool UPPAAL.

Extending timed automata with resource information, substantial effort for efficient analysis of Priced Timed Automata with respect to optimal infinite scheduling as well as design of a multi-priced zone datastructure supporting optimal reachability for Multi-Priced Timed Automtata has been made.

Extending timed automata with probabistic information, support for probabilistic reachability analysis for Probabilistic Timed Automata using a symbolic abstraction/refinement partitioning algorithm has been designed and implemented as a branch (UPPAAL-Prob) of the tool UPPAAL.

A combined probabilistic and priced extension of timed automata (PPTA: Probabilistic Priced Timed Automata) has been considered and promises to be an important model for representing real-time systems with resource constraints where e.g. resources are subject to failures, and where timed systems are subject to random phenomena. The central question has been to consider (un)decidability of the so-called cost-bounded probabilistic reachability (CBPR) question, i.e., is the probability to reach a set of goal states (within a deadline) with cost at most c, higher than p? Classes of PPTA are identified for which this problem is undecidable and classes for which it is decidable.

In **T2.2 (Abstraction, Refinement, and Compositionality),** major progress has been made (see also the list ff significant results below).

Support for various refinement relations between timed automata models has been obtained using reductions to timed games, allowing the branch UPPAAL-Tiga to be used.

Complementary abstraction techniques have been fully developed using predicate abstraction, an approach that has been proven quite successful for software model-checking, and the framework of three-valued abstraction in traditional model-checking has been developed for continuous-time Markov processes.

Counterexample generation algorithms have been developed, realized, and integrated into the predicate abstraction approach, yielding a CEGAR (Counter Example Guided Abstraction-Refinement) setting for probabilistic programs, i.e., programs with random assignments. This allows for the automated verification of parameterized systems. Besides, compact representations of counterexamples have been developed using regular expressions. Further results that are relevant to abstraction are the development of efficient algorithms for checking probabilistic simulation. The worst-case time complexity of these new algorithms is quadratically faster than the algorithms known so far. The key to this result is the use of parametric network flows. It is fair to say, that the progress within this task is ahead of the project schedule.

Finally, in **T2.3 (Approximate Analysis Techniques)** fruitful results have been established for model checking probabilistic models using discrete-event simulation rather than with numerical analysis techniques. Theoretical results have been achieved together with algorithms, and experiments have carried out to compare the results with model checking based on hypothesis checking, another variant of simulation. The discrete-event simulation techniques have also been realized in the model checker MRMC. These results are complemented by a minimization algorithm for acyclic phase-type distributions. Such

minimization is important to minimize the state-space representation of non-exponential distributions that are approximated by phase-types.

Significant results:

1. Decidability results for optimal infinite scheduling for Priced Timed Automata using mean pay-off as well as discouting metrics.
2. Decidability and efficient data-structures supporting Pareto-optimal reachability for Multi-Priced Timed Automata
3. Heuristic guided search engines for exploration of timed automata using Russian Dolls principle.
4. Efficient abstraction/refinement algorithm for probabilistic reachability analysis of Probabilistic Timed Automata implemented in UPPAAL-Prob.
5. Undecidability results for cost-bounded probabilities in PPTA (Probabilistic Priced Timed Automata) with three clocks, and some decidability results on arbitrary cost non-Zeno PPTA.
6. Counterexample-guided abstraction refinement of MDPs (Markov Decision Processes).
7. Advances in Three-Valued Abstraction of CTMDPs (Continuous-Time MDPs) and application to stiff Markov chains of systems biology.
8. Compact representations of PCTL counterexamples using regular expressions.
9. Effective procedure to minimize acyclic phase-type distributions.
10. Application of satisfiability-modulo-theory solving (SMT) to discrete-time probabilistic hybrid systems.
11. Discrete-event simulation of CSL model checking on CTMCs.

There are no deviations from the original planning in Annex I. In fact, more results in WP2 have been achieved so far than originally planned.

3.3 *WP3 – Implementation*

The main research objectives of WP3 are twofold.

First, within task **T3.1 (Controller Synthesis and Scheduling)**, our objective is to improve the understanding of synthesis problems defined on rich models suited for the modelling of embedded systems. In particular, we want to study synthesis problems for models where quantitative aspects of those systems can be modelled adequately. For example, models should allow us to specify and solve algorithmically scheduling problems. For that purpose, we are studying synthesis problems on finite state game structure, timed game structures defined using timed automata, automata models extended with probabilities, and automata models extended with costs. In the future, we also plan to study the combinations of those features. During the first year of our project, we have made substantial progresses in model-checking controllability properties.

The main results in this line of research are as follows:

- We have established new fundamental results of the Alternating-time Temporal Logic (ATL*). This logic is an extension of the temporal logic CTL* in which controllability properties can be expressed explicitly. The new results are both related to the complexity of decision problems and on expressiveness properties of that logic.
- We have shown how to synthesize winning strategies for games with imperfect information. Games of imperfect information are very natural for modeling embedded control design problems. Indeed, in most embedded systems, the controller has to take decisions from a partial (and so imperfect) information about the state of the system to control. This information is typically acquired using finite precision sensors. We have obtained new results for timed systems, and the techniques developed in this line of research has been implemented into a prototype. In the near future, those algorithms will be incorporated into the tool UPPAAL-Tiga. The first application of those techniques have allowed us to solve a case study provided in the context of this project by the HYDAC compagny.
- We have also studied reachability objectives for Continuous Time Markov Decision Processes, and in particular time-bounded reachability. This new results allow us to synthesize optimal policies to reach a set of states within a certain deadline.

Those results and their related publications are summarized in the deliverable D3.3. The objectives that were identified in our research proposal for task T3.1 for year 1 have been met and several new perspectives have been open for the sequel of the project.

Second, within task **T3.2 (Implementability and Code Generation),** our objective is to study the transfer of properties established on abstract models into concrete implementations automatically. This problem is particularly challenging for timed models. Indeed, in timed models time elapsing is measured using real-valued variables while in implementations, time elapsing is measure by counting ticks of a discrete clock with finite precision. During 2008, we have made significant progresses in this line of research. Here is a brief summary of the most significant results that we have obtained:

- We have now a clear understanding of the relationship between several notions of robustness and how to transfer properties from robust models into implementations. For that we have defined a notion of robustness for timed automata. We have shown that when a timed automaton satisfies robustly a property then this property can be transferred into an discrete time implementation. The classes of properties that we are able to handle with those results are those definable in LTL, so encompassing both safety and liveness properties. Theoretical results for more expressive timed logics have also been obtained.
- Algorithms for checking the robust satisfiability of a property by a timed model have been defined. To enable efficient implementations of those new theoretical results, a symbolic algorithm for robust satisfiability of safety properties has been defined for networks of timed automata. This algorithm has been implemented within the tool UppAal. Preliminary results are encouraging.
- Two alternative notions of robustness have also be investigated. First, one notion applicable for finite life-time systems or systems with resynchronization have been studied. This notion could lead in the future to efficient new algorithms applicable to classes of systems that are important in practice. Second, a new notion of

robustness based on probabilistic semantics has been investigated. Preliminary theoretical results are now available and should lead to new developments soon.

Those results and their related publications are summarized in the deliverable D3.1. The objectives that were identified in our research proposal for year 1 have been met and new perspectives have been open for the sequel of the project.

3.4 *WP4 – Testing*

During the first project year, focus in WP4 has been on development of the theoretical foundation being a substantial part of task **T4.1 (Test Generation)** and deliverable **D4.1 (Quantitative Testing Theory**). Such a foundation is a prerequisite for further work in the project on tool plug-ins for quantitative testing. More specifically, work has been concentrated on the definition of a sound and complete conformance relation – both with respect to real-time and also with respect to general quantitative aspects.

As for time, a series of timed *ioco* relations have been defined, and for one of them, an on-the-fly timed testing algorithm has been developed which uses timed automata as specification formalism. The algorithm has been implemented in the on-line testing tool TorX.

When testing quantitative aspects of implementations, the observations are always made within certain limits of uncertainty. This has been addressed by introducing *quantitative transition systems* and a corresponding quantitative *ioco* conformance relation. An implementation conforms to a specification as long as it is functionally correct (i.e. delivers only outputs that are expected) and deviates in the quantitative part by at most ε. Also, the more challenging question of finding out by testing which ε is the smallest such that the IUT conforms to the specification with respect to the conformance relation has been solved. Furthermore, sound and complete testing algorithms have been developed.

Our work in the period has also advanced on real-time test generation using the UPPAAL-tool suite. A new version of UPPAAL-Tron has been developed (beta 5) along with a User's Manual. A GUI for UPPAAL-Tron is under development. We have also demonstrated how to formulate offline test generation as a game problem and using UPPAAL-Tiga (with both full and partial observability) to synthesize test cases based on winning strategies. This allows usable and effective test cases for more general (liberal/non-deterministic) specifications to be generated given a test purpose or coverage criteria. These activities will be described in greater detail in future deliverables on test generation.

3.5 *WP5 – Case Studies, Tools, Dissemination and Exploitation*

Work package WP5 is concerned with case studies (T5.1), tools (T5.2), and dissemination and exploitation (T5.3).

T5.1 Case Studies

Concerning case studies (T5.1), Quasimodo plans to carry out a series of challenging case studies, provided by the industrial partners, in which related families of models are used for (quantitative) analysis, code generation, and test generation. The case studies are used to demonstrate and challenge the usefulness of the developed methods and tools, and to assess their strengths and weaknesses. To accomplish this, it is important to apply them on realistic problems. Therefore, case studies were to be selected that are close in spirit to products that are under development by the industrial partners.

The first-year goals were to identify and describe the case studies, and to perform initial modelling for these cases. Four case studies were identified provided by the Quasimodo industrial partners:

1. the Accumulator Charge Controller, provided by HYDAC;
2. the self-balancing scooter, provided by CHESS;
3. a Wireless Sensor Network, provided by CHESS;
4. the attitude and orbit control software for the satellites Hershel and Planck, provided by TERMA.

Deliverable D5.2, "Preliminary description of case studies", provides detailed descriptions of these case studies. Moreover, in addition to describing the case study systems, D5.2 identifies for each case study several modelling, verification, implementation, and testing challenges and research questions.

Two of the case studies, viz. the Accumulator Charge Controller (HYDAC) and the Wireless Sensor Network (CHESS), in particular the gMAC protocol of this network, were elaborated during the first year. Deliverable D5.5, "Case studies: Models", describes the approaches to modelling and analyses of these cases, and, where applicable, the first results.

For the Accumulator Charge Controller several Simulink and Stateflow models (Matlab), Timed-Gamed Automata models (UPPAAL-Tiga), and PHAVER-models were developed. The Simulink-Stateflow models, using the simulation capabilities provided by Simulink, enabled us to get various insights into the functioning of the different systems.
Moreover, with the Simulink-Stateflow models we could experimentally validate (no proof) some properties: the HYDAC controllers always keep the pressure in safe margins, and the HYDAC ACC controller always uses considerably less energy than the HYDAC 2-point controller.

The Timed-Gamed Automata and PHAVER models were used for both analysis and controller synthesis. The results show that the controller synthesized with UPPAAL-TIGA is robust whereas the robustness of the HYDAC controller is unsettled yet. Moreover, the simulation reveals that the performances of the synthesized controllers provide a vast improvement of the HYDAC ACC controller (33%) and of the HYDAC 2-point Controller (45%).

For the gMAC protocol of the Wireless Sensor Network, Timed Automata models (UPPAAL) and MoDeST models were developed. The Timed Automata models were used to analyse node synchronization, and in particular the minimum waiting period (guard time) in a node which guarantees synchronization. For a fully connected network, i.e., all nodes are connected to each other, a minimum waiting period could be calculated as a function of the

topology, the drift and jitter of the clocks, and the allocation of transmission slots. Moreover, the models and their analysis resulted in a better understanding of the protocol, and more insight for both academic and industrial partners.

The MoDeST models of the gMAC protocol were used to analyse, using discrete event simulation, probabilities of collision rates, the effectiveness of the collision detection mechanism, and how this affects performance and energy consumption also taking into account the number of active slots. It was shown that the number of active slots influences the number of collisions enormously, but that very many active slots are needed before the number of collisions actually tends to go to 0.

Work on the Hershel/Planck software-case (TERMA) has recently started. A Timed-Automata model for the schedulability analysis part of the case study is partially complete. No work on the modelling of the ACS software for system level testing has been done yet.

Overall WP5 has made good progress in quantitative modelling of the cases, although more progress on the Hershel/Planck software-case (TERMA) had been desirable. This delay was in part caused by the delay of the release of this case due to confidentiality issues (See Section 5.2).

The most significant results of T5.1 are:

- four significant industrial case studies have been identified and described in detail (see Deliverble 5.2);
- initial modelling of the case studies has been done; in particular, the HYDAC Accumulator Charge controller has been modelled in detail, and progress in automatic controller synthesis for this case has exceeded our plans and expectations.

T5.2 Tools

For tools (T5.2), the plan is to develop approaches and plans for tool plug-ins and tool-chain integration. Due to the fact that the main (and only) tool provider company in the consortium, Inchron GmbH, left the project, and that subsequently the planned replacement, The Mathworks, despite an initial agreement, did not wish to join the consortium, this activity suffered delays (See Section 5.2).

Current, initial plans for tool plug-ins and tool-chain integration are given in **D5.4: "Plan for integration of tool components"**. This deliverable describes the current status as to the development of the tools of the Quasimodo consortium. This set of tools include

- a number of tools aiming at probabilistic and stochastic analysis for Markovian models or probabilistic extensions of timed automata, and
- a collection of branches of the tool UPPAAL – based on timed automata – for verification, scheduling, controller synthesis and testing.

For the probabilistic tools several experiments with exchange of models between tools – lincluding the external tool PRISM – has been made and are planned in order exploit the most efficient analytical approach for a given example. For the real-time tools based on UPPAAL, interaction with external UML-based tools as well as Matlab/Simulink has been

carried out. In particular, realization of strategies synthesized by UPPAAL-Tiga as S-functions of Simulink has been successfully made for the HYDAC case. In future of the project effort will be made towards systematizing this transfer, as well as establishing links between UPPAAL-Tron and Simulink, as a way of obtaining simulation of timed automata models in the context of more complex continuous behavioural components.

Deliverable D5.4 gives a sound and healthy approach for future tool integration. We expect that despite Inchron GmbH leaving the project consortium, Quasimodo will be able to deliver a useful tool environment for model-based analysis, implementation, and testing of quantitative system properties.

T5.3 Dissemination and Exploitation

The activities and plans for dissemination and exploitation (T5.3) are described in Deliverable D5.3: "Dissemination and use plan". Different activities have, and will be organized in this respect. In the first place, a Quasimodo web site has been created (http://www.quasimodo.aau.dk/; Deliverable D5.1: "Quasimodo website"). Moreover, this includes (the organization of) conferences, symposia, (summer-) schools, local and international workshops, and courses in which Quasimodo is involved and where Quasimodo results are presented, related projects, programs, and networks where Quasimodo consortium is involved and where there are opportunities for cross-fertilization, and the initial ideas of the industrial partners about potential exploitation of the Quasimodo results in their organization. Two dedicated Quasimodo workshops are planned for 2009 (during the International Formal Methods Week) and 2010, respectively.

3.6 *Use of Resources*

The following table shows the planned and real (actual) staff (person month) usage per work package per partner for ***staff being paid*** from the Quasimodo budget. P=planned, R=real person months.

	WP0		WP1		WP2		WP3		WP4		WP5		Total	
Partner	P	R	P	R	P	R	P	R	P	R	P	R	P	R
AAU	6	5	2	2	3	2	3	4	0	0	1	2	15	15
ESI	0	0	4	0	4	0	3	0	3	7	7	7	21	14
CNRS	0	0	0	0	3	3	5	4	0	0	2	1	10	8
RWTH	0	0	2	1	6	6	0	1	0	2	3	1	11	11
SU	0	0	2	1	3	4	0	0	0	0	5	3	10	8
CFV	0	0	0	0	1	0	9	0	0	0	0	0	10	0
Terma	0	0	1	0	0	0	0	0	0	0	3	1	4	1
Chess	0	0	0	0	0	0	0	0	0	0	5	8	5	8
Inchron	0	0	0	0	0	0	2	0	0	0	1	0	3	0
Hydac	0	0	1	1	0	0	0	0	0	0	4	2	5	3
Total Y1	6	5	12	5	20	15	22	9	3	9	31	25	94	68
Total Y2	6	0	16	0	24	0	19	0	15	0	22	0	102	0
Total Y3	6	0	6	0	10	0	6	0	13	0	36	0	77	0
Total	18	5	34	5	54	15	47	9	31	9	86	25	270	68

A total of 94 pm has been planned for the first year whereas 68 have been delivered. This discrepancy is caused by 1) The partner Inchron left the project before project start and has thus performed no work on the project; 2) No all partners have managed to hire new staff from the beginning of the project, e.g., CFV (See section 6) and ESI.

The recruitment problem for CFV has been solved. Raffaella Gentilini has been employed via the project the project starting on January 1st 2009 . Similarly, ESI has spend less person months that planned as ESI/UTwente has not managed to hire staff from the beginning of the project, and moreover, Ed Brinksma needed to leave ESI before the year and causing a delay in personnel replacement. Again remark that more
ESI personnel have worked on the project without incurring a salary costs to the project. The recruitment problems for ESI have now been solved. Jiansheng Xin and Julien Schmaltz are fully employed on Quasimodo. Julien Schmaltz started March 1, and Jiansheng Xin around November 11.

Chess has overspent compared to the plan. However, they have contributed with two case studies during the first year. Chess has confirmed that they will fulfil their obligations in WP1 and continue to support the case studies in WP5 within the existing budget.

Less work than planned has been invested in WP1. This is mostly caused by the delay in replacing Inchron and establishing a suitable notation and tool suite, i.e., Mathworks/Simulink versus SCILAB versus UML. The deviation for WP3 is caused by a partner (CFV) not having hired personnel for the task. Instead the work has been carried out by other staff members without incurring costs to the project.

For WP4 we spend somewhat more effort than planned. This is in part because some of the theory was more complicated than anticipated, and further understanding of some of the tricky differences between versions of our testing theories were desired; and in part because some work has been initiated beyond the planned work on testing theory, e.g testing framework, algorithms and tools. A little under-spending has occurred for WP5, mainly caused by Inchron and delay in some case study descriptions. However the spending is not equally balanced among all case studies as two (Hydac and Chess WSN) has received more attention than the others during year 1.

In total 68 person months (equalling approximately 6 person years) has been delivered by Quasimodo. The deliverables and milestones have all essentially been met, and in addition the work has resulted in around 50 refereed scientific (conference or journal) publications.

The project meetings have had a very high attendance rate (30-50 researchers). Thus the support by the EC has produced a lot of good quality research on quantitative system properties, especially compared to the budget.

3.7 *Summary of Milestones*

The preceding presentation has summarised the progress that have been made within Quasimodo during the first year.

The project kick off meeting was held January 15-16, 2008, at Aalborg University, Denmark (**M1.1**).

Our industrial partners have proposed four challenging case studies as described in D5.2 (**M2.1**), with significant progress on both modelling and validation made on two of the case studies, the Wireless Sensor Network (CHESS) and the Accumulator Charge Controller (HYDAC).

For the former case study, node synchronization has been analysed using UPPAAL models. For the latter case study, controller synthesis has been applied to obtain a near optimal, correct, safe and robust controller, that is 30%-40% better than the existing one in terms of energy consumption (**M3.3**). The work on this case study points to a useful tool-chain, with UPPAAL-Tiga performing synthesis on abstract, discrete models, PHAVER performing verification of correctness on continuous models, and Simulink offering performance analysis on stochastic models.

The HYDAC case study also points to a number of open problems for Priced Timed Automata with positive and negative cost-rates, as well as the need to identify a formal quantitative modelling formalism corresponding to the stochastic models of noise provided by Simulink (**M3.4**).

A plan for the tool components to be delivered and their integration with external and industrial tools is described in D5.4 (**M2.2**). For probabilistic tools of the consortium interaction with the external tool PRISM has been demonstrated and further and closer interaction is planned to be pursued in the next year. For real-time tools of the consortium –

all though not as advanced as originally envisioned due to the withdrawal of a partner – the plan shows a viable path of integration of Quasimodo tool components in the Mathworks Matlab/Simulink tool-suite, and an investigation of the fit with the open source Scilab tool suite. Also, support for verification and test-case generation for UML State-chart models is under development.

During the first year we have in D1.1 identified a number of formalisms for specifying and modelling quantitative information. The starting point for these extensions is (timed) automata theory or Markov Decision Processes. Specifically, important proposed and investigated formalisms involve priced extension of timed automata (for modelling and reasoning about resources) and probabilistic extensions of timed automata (for modelling and reasoning about uncertainties) as well intial work on combined priced *and* probabilistic extensions of timed automata. All of these have a precise formal semantics in terms of quantitative labelled transition systems (a transition system, which in addition to transition action labels are labelled with one or more quantities….). establishing collectively a framework for quantitative models (**M3.1**)

A quantitative version of the *ioco* conformance relation between a system model and its implementation is defined in D4.1; An implementation conforms to a specification as long as it is functionally correct and deviates in the quantitative part by at most ε. In D3.1 we have defined several notions of robustness and how to transfer properties from robust models into implementations. We have developed an efficient symbolic algorithm for robustness checking of timed automata and implemented this in UPPAAL (**M3.2**).

Additional goals have been achieved by Deliverables D2.1 and D3.3:

- Deliverable D2.1 describes the significant effort of the project towards theory and tools for model checking real-time probabilistic models, as found implemented in the new branch UPPAAL-Prob.
- Deliverable D3.3 describes the substantial effort of the project towards model checking of controllability properties, including implementation of controller synthesis under partial observability as implemented in UPPAAL-Tiga.

4. Deliverables and milestones tables

TABLE 1. DELIVERABLES[5]

Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I (proj month)	Delivered Yes/No	Actual / Forecast delivery date	Comments
D1.1	Modeling quantitative system aspects	1	ESI/RU	R	PU	12	Y	12	
D1.2	Design Notations	1	SU	R	PU	12	Y	12/24	*)
D2.1	Model checking real-time probabilistic models	2	AAU	R+P	PU	12	Y	12	***)
D3.1	Transfer of correctness properties from model to implementation	3	ULB	R	PU	12	Y	12	
D3.3	Model checking of controllability properties	3	ULB	R+P	PU	12	Y	12	****)
D4.1	Quantitative Testing Theory	4	ESI/TW	R	PU	12	Y	12	
D5.1	Quasimodo Website	0	AAU	O	PU/CO	1	Y	1	
D5.2	Preliminary description of case	5	SU	R	PU	6	Y	12	**)
D5.3	Dissemination and use plan	5	ESI	R	PU	6	Y	12	**)
D5.4	Plan for integration of tool components	5	AAU	R	PU	12	Y	12	
D5.5	Case Studies: models	5	RWTH	R	PU	12	Y	12	

[5] For Security Projects the template for the deliverables list in Annex A1 has to be used.

***)** Concerning D2.1 on design notations which we find only partially completed due to the uncertainty of the partner replacement, we propose to write an updated version by month 24. This will be reflected in our proposal for an updated Description of Work.

**) In agreement with the project officer, these deliverables were submitted to the EC by the end of year as one package along with the remaining first year deliverables.

***) The prototype tool component to be delivered with D2.1 concerns a model checkers for probabilistic timed automata. The component named UPPAAL-Prob is a branch of the UPPAAL model-checker extended with probabilities. It is available by contacting the developers (Kim G. Larsen kgl@cs.aau.dk). It is in working condition but is still being matured before its public release expected by June 2009.

****) The prototype tool components to be delivered with D3.3 is model-checking of implementability of timed automata models (robustness analysis) and controller synthesis under partial observability. These functionalities are available in the latest developer snapshot of UPPAAL (version 4.1) and UPPAAL-Tiga available at www.uppaal.com. The improved algorithm described in D3.1 section 3 will be available in the next developer snapshot (version 4.1.1) forseen in March 2009.

Milestones

TABLE 2. MILESTONES							
Milestone no.	Milestone name	Work package no	Lead beneficiary	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments
M1	Project Start	All	AAU	M1	Yes	15+16 Jan'08	Kickoff meeting
M2	Definition Phase	All	ESI	M6	Yes	M8	
M3	Modelling Formalisms	All	SU	M12	Yes	M12	

Milestone M1 is to be verified through a kick-off meeting. The Quasimodo kick-off meeting was held 15+16 january 2008 at Aalborg University, Denmark.

Milestone M2 is to be verified through availability of 1) a precise descriptions of case studies, 2) a plan for tool components and their integration in industrial tool chain.

Milestone 3 is to be verified through the availability of 1) a semantic foundation of quantitative models in terms of labelled transition systems including semantics of composition of models, refinements between models, 2) a formal definition of conformance and robustness between quantitative models and implementations, 3) first models of case studies, and 4) quantitative extensions identified by the needs of case studies.

We believe that we have reached these milestones as discussed in Section 3.6.

5. Project management

Please use this section to summarise management of the consortium activities during the period. Management tasks are indicated in Articles II.2.3 and Article II.16.5 of the Grant Agreement.

Amongst others, this section should include the following:

- *Consortium management tasks and achievements;*
- *Problems which have occurred and how they were solved or envisaged solutions;*
- *Changes in the consortium, if any;*
- *List of project meetings, dates and venues;*
- *Project planning and status;*
- *Impact of possible deviations from the planned milestones and deliverables, if any;*
- *Any changes to the legal status of any of the beneficiaries, in particular non-profit public bodies, secondary and higher education establishments, research organisations and SMEs;*
- *Development of the Project website, if applicable;*
- *Use of foreground and dissemination activities during this period (if applicable).*

The section should also provide short comments and information on co-ordination activities during the period in question, such as communication between beneficiaries, possible co-operation with other projects/programmes etc.

For Grant Agreements related to infrastructures (Annex III of the Grant Agreement), the access provider shall include a section in the periodic reports on the access activity, indicating the membership of the selection panel as well as the amount of access provided to the user groups, with the description of their work, and the names and home institutions of users.

5.1 *Consortium management tasks and achievements*

The day-to-day management of Quasimodo is handled by the management team, which consists of the Coordinator, Co-coordinator and Administrative Project Manager

During the first project period, the main management tasks have included:

- The project started as planned on 1st of January 2008 and the kick-off meeting took place in Aalborg.
- All partners participated in the first General Assembly and the meeting was evaluated as very successful.
- The research in the work packages have been coordinated primarily via mail and telephone, but also in physical working meetings (see Section 5.3); the communication within and between work packages works well.
- A successful mid-year General Assembly took place in Aachen.
- A Quasimodo project website with both public and private area has been launched and will be continuously updated and developed.
- A key person Ed Brinksma had to leave the consortium to take up a new position, but Dr. ir. Jan Tretmans has effectively taken over the duties as WP5 leader
- The consortium has successfully changed Administrative Project Manager to Marlene Kræmmer Sparre due to maternity leave.

- Organizing kick-off and project meetings
- Ensuring efficient communication within the consortium
- Managing the process of partner substitution and updating DoW An amendment will be send soon after this periodic report
- Distributing pre-financing to all partners
- Project reporting, monitoring and review

Moreover, the management team endeavours to assist the consortium on day-to-day management issues and to communicate information and guidelines from the EC. As such, the Quasimodo management team was represented at Coordinators Day 17 of December 2008 in Bruxelles. The meeting focused on project and cost reporting.

Finally, it is the impression of the management team that the consortium performs well, and the individual WPs interacts satisfactorily and in general the progress is according to schedule.

5.2 *Problems and solutions*

Two main problems have emerged during the first year.

The first main problem was that one of the original partners, Inchron Gmbh, had to leave the project just before project start due to a change in its management-board, and as consequence, made a strategic change in the company's priorities and use of critical personnel resources. Inchron is a SME tool provider developing simulation tools for execution time- and schedulability- analysis of embedded systems.

Whilst their departure is not critical to the overall scientific goals of the project some adjustments to the work programme is needed. This includes removing some sub-tasks related to resource modelling (e.g. library of standard resource model-components) and tool-componts for execution time analysis, and schedulability analysis and simulation. The exploitation aspect is more affected.

One of the main goals of the project is that the tool components that will be developed in Quasimodo will be able to function as plugins in the industrial tools that companies (inside and outside) Quasimodo actually used. To satisfy our exploitation ambitions we have sought another SME tool provider to become partner. We have contacted companies that we found suitable for the project and were able to join the project. However, none of our attempts were successful. Next we contacted one of the main industrial players in the area, i.e., the Mathwork's Matlab/Simulink tools. Through such collaboration we see a unique opportunity to deliver components that will work with these specific tools, and thereby possibly achieve high impact. In fact we had an oral understanding (reached in a meeting at the DATE conference March 2008 between Pieter Mostermann from Mathworks and Kim G. Larsen and Ed Brinksma from Quasimodo) with Mathworks between of an arrangement where they would be a collaborator in the project. However, after preparation of the new version of the DOW and during formalisation of the agreement, they informed us via mail December 4 2008 that they unfortunately could not presently find the resources (staff) for the tasks.

However, we still believe that targeting Matlab/Simulink suite would be very beneficial, and as we have mentally already started the process, and have used the tool-suite in the case studies we are considering proceeding with this - without Mathworks – with the consortium assuming

these tasks (and left over resources). This solution has been proposed to the project officer whom in principle have accepted it, but also suggested us to consider the SciLab tool-suite open source competitor. This is indeed an interesting proposal which we have given serious considerations. Our conclusion is however, that Mathworks/Simulink is the defacto tool that is being used in European industries, and therefore we seek to continue integration with this tool to increase impact. At the same time we will further evaluate Scilab in the project and invite representatives (e.g. Antoine Petit, Director of INRIA Paris-Rocquencourt) to present its capabilities in greater detail to determine if specific integrations/collaborations will beneficial. The consequences on the work programme will be clear from an forthcoming revision of DOW (see also Deliverable 5.4 on tool integration).

The delay in settling this issue has also had a specific impact on Deliverable 1.1 on design notations, which could not be completed to our satisfaction, as the notation (both syntax and semantics) depends on the specific target language/notation to be extended with quantitative notions. We propose to split this deliverable into two versions; one delivered by month 12 now and an update after month 24.

The second main problem concerned confidentiality of information about some of the case studies. Although it was agreed within the consortium during the application process that the case studies should be public this could not be fully realised in practice. At first, Chess wished to file a patent of their gMAC technology part of the WSN case study. Before the patent application was filed, technical information on this was confidential. To allow work on the case to progress the consortium – after quite some discussion – agreed to sign an additional NDA (Non-disclosure agreement) with Chess.

A similar problem occurred with the Terma case. Whereas Terma was internally willing to release its documentation to the consortium, it was bound to project contracts (with e.g. ESA) requiring confidentiality. Again the solution was to have the members of the consortium needing access to the technical documentation sign an extra NDA.

However as a side effect *not all work on the case can be reported in a public deliverable*. This concerned in particular Deliverable 5.2 (Preliminary description of case studies) and 5.5 (first models of case studies). Moreover, the process caused a delay in the modelling work on the Terma case, causing somewhat less progress being made than anticipated. The Chess patent is now filed and the information related to the case public. Details on the Terma case are still restricted.

We will propose in an updated Annex-I that deliverables concerning case studies may have both a public and a confidential part.

Finally a key person Ed Brinksma, the Scientific Director of ESI, left ESI and thus Quasimodo to take up the prestigious position as Rector magnificus (vice-chancellor) of the University of Twente. Besides being visionary and influential he was also leader of WP5. Unfortunately this event coincided with the start of the planned project reporting for year 1. ESI has appointed a good substitute as Quasimodo representative and WP5 leader: Dr. ir. Jan Tretmans, and ESI will otherwise fulfil its obligations towards the project.

5.3 *Project Meetings*

Quasimodo has held two very successful project assembly meetings. Minutes are available at the project website.

Meeting 1 was the kick-off meeting held and organized by AAU January 15+16 2008. The presentations included a project overview, partner presentations, preliminary presentations on the case studies, and about 10 technical presentations. More than 30 international researchers were present. Also, a management board meeting took place. Minutes and slides from the meeting and general assembly are available at the internal Quasimodo website.

Meeting 2 was held in Aachen June 2+3 2008 organized by RWTH. The presentations included a project status, presentations on the case studies, and about 12 technical/scientific presentations related to the work packages. Nearly 50 international researchers associated with the partners were present showing an enormous interest in the Quasimodo project. Also, a management board meeting took place. Minutes and slides from the meeting and general assembly are available at the internal Quasimodo website.

Meeting 3 will be held in Bruxelles 17+18 of February 2009 organized by ULB.

In addition to these larger Assembly Meetings, project members have met at other occasions to do technical work:

- April 15-18 2008: Kim G. Larsen visiting CNRS/LSV (WP3: weighted timed automata with energy constraints).
- May 19-21: Working Meeting in Aalborg (WP1+WP2: Priced Prob. Timed Automata)
- October 31: Jan Tretmans visiting AAU (WP4: Model-based testing and quantities)
- October 31: Working Meeting at CHESS, Haarlem, Netherlands (WP5: Case Study)
- Dr. Pierre-Alain Reynier (formerly at ULB, now at University of Marseille) visited ULB from Dec. 15 until Dec. 18 to work on Quasimodo related research problems: "Synthesis of observations for control" (WP3)
- December 15-19 2008: Patricia Bouyer and Nicolas Markey visiting Aalborg University. (WP3: weighted timed automata with energy constraints).

5.4 *Project planning and status*

Quasimodo has submitted all the required deliverables, and met its main milestones, and work is in several areas progressing beyond the plan. Obviously, the consequences of the missing partner have affected the work as reflected in the problems and solutions in Section 5.2. The updated description of work is expected urgently following the completion of this reporting period.

5.5 *Use of foreground and dissemination*

5.5.1 Presentation activitites

See also Deliverable 5.3 (dissemination and use plan).

Press releases of Quasimodo

- RWTH Themen, Ausgabe 1/2008, February 2008.
- AAU.dk: http://presse.aau.dk/nyheder/3443565 (AAU)
- tv2nord.dk: http://tv2nord.dk/default.asp?PageID=5&NewsCategoryID=1&NewsID=168990 (AAU)
- Elektronik & Data / Ugens Erhverv: http://ue.dk/nyhedsarkiv/16716.aspx (AAU)
- Comon: http://www.comon.dk/index.php/news/show/id=34333 (AAU)
- epn.dk (Jyllands-Postens erhvervssite): http://epn.dk/teknologi/it/article1229968.ece (AAU)
- CRN.dk http://www.crn.dk/index.php/news/show/id=27156 (AAU)
- Børsen, s. 17 i dag, see resumé at http://mh.infopaq.net/081E4238-4CA9-492e-96AF-A4CFDDCB011C/nyheder.asp?L=1&R=100&M=1&S1=100&S2=100&MatchCriteria_UID=&V=1&CallPage=arkivliste.asp&ArtNo=7605900 (AAU)

The Quasimodo project has been presented in the following venues

- Quasimodo Fiche made for the EC (AAU)
- Quasimodo was presented in ERCIM news speciel issue on safety critical systems (AAU) http://ercim-news.ercim.org/content/view/468/699/
- CNRS has presented Quasimodo in a meeting of the french project VERAP (Approximate Verification of Probabilistic Systems, http://www.lri.fr/~mdr/verap) on April 11th 2008.
- CISS VIP Magazine 2008

Scientific presentations of Quasimodo work has been done at the following occasions:

Invited Talks and Lecures:

- Prof. JF Raskin (ULB), QAPL workshop, satellite of ETAPS 2008, Budapest, Hungary, April 2009, title of the invited talk: "On Optimal Strategies in Timed Reachability Games", one hour. (http://wwwtcs.inf.tu-dresden.de/ALGI/qapl08/)
- Prof. JF Raskin (ULB), ARTIST2-NoE China Summer School, Shanghai, China, July 2008, title of the invited lecture: "Timed Automata and Extensions for Modeling, Verification and Synthesis", six hours. (http://www.artist-embedded.org/artist/Artist2-Summer-School-in-China.html)
- Dr. Laurent Doyen (ULB-EPFL), MOVEP08, Rennes, France, June 2008, title of the invited lecture: "Games for Controller Synthesis ", (http://www.univ-orleans.fr/movep2008/).

- Katoen, Joost-Pieter (RWTH), Perspectives in Probabilistic Verification, in: 2nd IEEE International Symposium on Theoretical Aspects of Software Engineering (TASE), June 2008. (Keynote)
- Katoen, Joost-Pieter (RWTH), Performance Analysis and Model Checking – A Perfect Match, Talk, Invited Lecture Summerschool GLOBAN 08, Warsaw,Poland, September 2008.
- Katoen, Joost-Pieter (RWTH), Parameter Synthesis for Probabilistic Systems, Talk, Invited Talk at Opening MT-LAB, Copenhagen, October 2008.
- Katoen, Joost-Pieter (RWTH), Probabilistic Model Checking: Achievements and Challenges, Invite Talk at CDC Workshop on Stochastic Hybrid Systems, December 2008.
- Kim Larsen (AAU) Invited talk at Workshop of CDC, Tallin, Estonia, January 21-22, 2008.
- Kim Larsen (AAU), Invited talk at SSV08, Sidney, Australia, Feb 25-27, 2008
- Kim Larsen (AAU) Inivited lecture at WODES 2008, Göteborg, Sweden, May 28-30, 2008
- Jan Tretmans (ESI), Lectures at EJCP (Ecole Jeunes Chercheurs en Programmation), Rennes, May 29.June 6, 2008
- Jan Tretmans (ESI), Model Based Testing: Models for Test Cases, TestNet Industrial Testing Conference, Aalborg, Denmark Oct 3. 2008.
- Kim Larsen & Brian Nielsen (AAU), Invited lecture at Pan-European conference on Systematic Testing, Berlin June 4-5, 2008
- Kim Larsen (AAU) Invited lectures at Marktorberdorff summer school, August 5-17, 2008 .
- Jan Tretmans (ESI), Lectures at the TAROT Summer School, Bath, June 22-27, 2008
- Ed Brinksma (ESI), Lectures at the Artist2 Summer School in China, Shanghai, July 12-18, 2008
- AAU, ESI: Lectures at the ARTIST2 summer school in Europe, Grenoble, France, September 8-12, 2008 (Kim Larsen, Ed Brinksma).
- Dr. Patricia Bouyer (CNRS/LSV), GAMES'08, Warsaw (Poland), September 2008. Title: "Quantitative timed games".
- Dr. Patricia Bouyer (CNRS/LSV), TFIT'08, Taipei (Taiwan), March 2008. Title: "Model Checking Timed Temporal Logics".
- Dr. Patricia Bouyer (CNRS/LSV), Automata and Verification Workshop, Mons (Belgium), August 2008. Title: "Probabilities in Timed Automata".
- Dr. Nicolas Markey (CNRS/LSV), MOVEP'08, Nouan-le-Fuzelier (France), June 2008. Title of the tutorial: "Timed Systems".
- Dr. Nicolas Markey (CNRS/LSV), Automata and Verification Workshop, Mons (Belgium), August 2008. Title: "Infinite Runs in Weighted Timed Games with Energy Constraints".

Meetings arranged in relation to Quasimodo

  - SU: A summer School 'Fun with Automata' is planned for September 2008 dedicated to 3rd year Bachelor students.
- AAU: DaNES Simulink/Labview Course, April 7-10, 2008, Sønderborg, Denmark (25 participants).
- AAU: DaNES Tools Days, April 23-24, 2008, Aalborg, Denmark (30 participants).
- AAU: DaNES Mini Projects, May 22-23, 2008, DTU, Denmark.
- AAU: TestNet Testing Industrial Conference, October 30, 2008 (WP3: 80 participants). Quasimodo speakers Jan Tretmans and Kim G. Larsen.

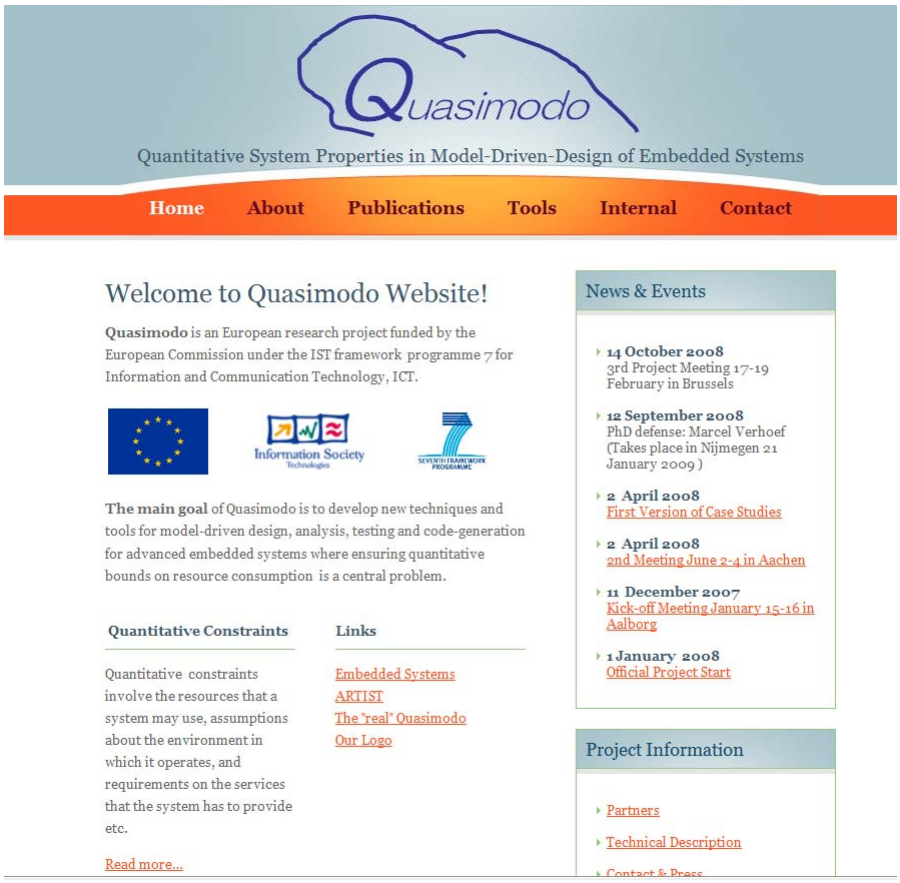
- CNRS: Summer school MOVEP 2008 (see http://www.univ-orleans.fr/evenements/movep2008/) about specifying, modeling, and verifying parallel and concurrent processes for control of real-time applications, reactive, and critical systems (Franck Cassez (CNRS), François Laroussinie (CNRS): steering committee, and Patricia Bouyer (CNRS), Ed Brinksma (ESI), Kim Larsen (AAU), and Jean-Francois Raskin (CFV): program committee. Nicolas Markey (CNRS): tutorial on timed systems).
- ESI/UT: Dutch IPA Spring Days on Integrated Formal Methods, May 2008.
- ESI/UT: Basic Course IPA for PhD students on Formal Methods, Autumn 2008.
- ESI: The ESI Symposium, presenting all ESI projects including Quasimodo, Dec. 4, 2008.
- ESI: Co-organization of Bits&Chips Embedded Systems, Oct. 9, 2008.
- ESI: Co-organization of “De Nederlandse Testdag” (The Dutch Testing Day), Nov. 27, 2008.
- ESI: Co-organization of INCOSE 2008 (18th Annual Int. Symposium of the Int. Council on Systems Engineering), June 15-19, 2008.
- ESI: CEST-ESI bilateral workshop in Korea, May 19-23, 2008.
- ESI: Organization of the Embedded Systems track on the Artemisia/ITEA Symposium, Oct. 22, 2008.

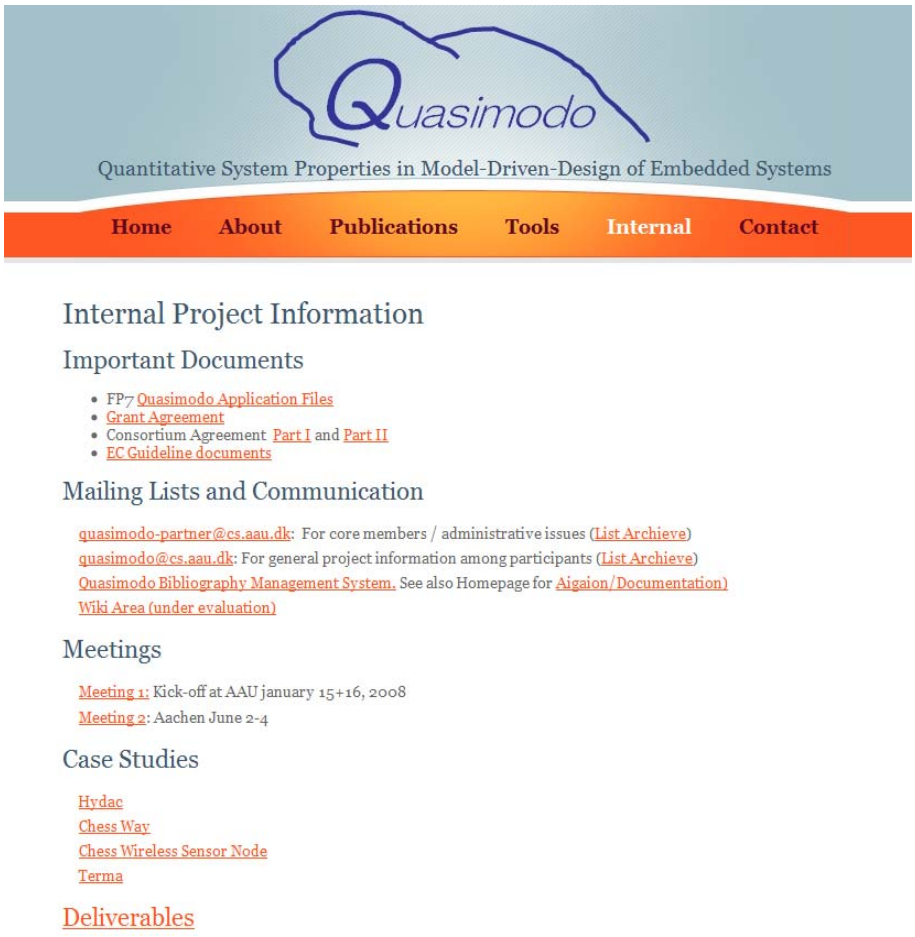
5.5.2 **Quasimodo website**

The Quasimodo web-site is available at http://www.quasimodo.aau.dk .

It has a public area containing a front page, a page describing the goals and objectives of the project, a page with the public scientific publications and deliverables, and a page containing a list of Quasimodo tools, and finally a contacts page containing contact information for the coordination team as well as project partners.

The private area contains working and administrative information for the project partners. It contains important EC documents such as the grant agreement and miscellaneous EC guides, and the consortium agreement. It also contains a list of the project assembly meetings (including slides of presentations and minutes), mailing lists, and a documents area for storing working documents related to the case studies and deliverables. More over it features a Bibliography Management System allowing members to report and query the scientific Quasimodo publications. It also contains a Wiki Area (under consideration as editing system for the industrial handbook).





5.5.3 **Collaboration with Other projects**

(see also deliverable 5.3)

- Artist Design, FP7 NoE
- GASICS, ESF project (CFV, AAU, CNRS)
- MULTIFORM, FP7 STREP (AAU, ESI, and several Quasimodo Partners affiliated)
- ESA Project COMPASS (Correctness, Modeling and Performance of Aerespace Systems), http://compass.informatik.rwth-aachen.de/ (RWTH)
- Collaboration with ESI project Wings (with ASML) is currently under discussion (modelling of a communication switch in Uppaal with Jeroen Voeten).
- Also Collaboration with ESI project Octopus (with Oce; www.esi.nl/octopus) is considered (modelling work of Georgeta Igna and Frits Vaandrager.)
- Collaboration with ARTS (Abstraction Refinement for Timed Systems; Dutch Science Foundation); modelling work by Faranak Heidarian and Frits Vaandrager.
- A number of other national projects on the topic of Model Driven Development for Embedded Systems.

5.5.4 **Publications list**

The research in Quasimodo has for year 2008 resulted in around 50 refereed scientific (conference or journal) publications. These are listed in work package order in Section 9. A browsable version is available online at the Quasimodo webpage http://www.quasimodo.aau.dk/publications.html.

6. Explanation of the use of the resources

TABLE 3.1 PERSONNEL, SUBCONTRACTING AND OTHER MAJOR DIRECT COST ITEMS FOR BENEFICIARY 1 FOR THE PERIOD			
Work Package	Item description	Amount	Explanations
Ex: 2,5, 8, 11, 17	Personnel costs	*235000 €**	*Salaries of 2 postdoctoral students and one lab technician for 18 months each**
5	Subcontracting	*11000 €**	*Maintenance of the web site and printing of brochure**
8, 17	Major cost item 'X'	*75000 €**	*NMR spectrometer**
11	Major cost item 'Y' …….	*27000€**	*Expensive chemicals xyz for experiment abc**
	Remaining direct costs	*15000€**	
	TOTAL DIRECT COSTS[6]	*363000€**	

* *The entries in italics are examples and purely for illustration*

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 1 AAU			
Work Package	**Item description**	**Amount**	**Explanations**
	Personnel costs RTD	33.189 €	Salaries for 2 researchers
	Personnel costs MAN	29.833 €	Salaries for co-coordinator, Adm. Project manager, secretary
	Remaining direct costs	6.275 €	Travel costs
TOTAL DIRECT COSTS*		69.297 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 2 ESI			
Work Package	**Item description**	**Amount**	
4,5	Personnel costs	67.535 €	Ed Brinksma: 0.43 pm (person months) Jan Tretmans: 0.94 pm Julien Schmaltz 10.23 pm Jiansheng Xing 1.99 pm
	Subcontracting		
	Major cost item "X"	7.856 €	Traveling
	Major cost item "Y"		
	Remaining direct costs		
TOTAL DIRECT COSTS*		75.391 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 3 CNRS			
Work Package	**Item description**	**Amount**	**Explanations**
2,3	Personnel costs	45.094 €	salaries for 3 researchers (7.5 PM)
2,3	Remaining direct costs	500 €	travel expenses
TOTAL DIRECT COSTS*		45.594 €	

[6] Total direct costs have to be coherent with the directs costs claimed in Form C

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 4 RWTH Aachen University			
Work Package	**Item description**	**Amount**	**Explanations**
1, 2, 3, 5	Personnel costs	53.404 €	Salary of one postdoc, and salaries of all participating RTD personnel in Quasimodo
	Personnel costs (other)	8.498 €	Salaries of supporting personnel, and costs for organising Quasimodo workshop
	Other direct costs	4.831 €	
TOTAL DIRECT COSTS*		66.733 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 5 SU (UDS)			
Work Package	**Item description**	**Amount**	**Explanations**
1,2,5	Personnel costs	42.418 €	Salaries of all participating RTD personnel in Quasimodo
	Remaining direct costs	1.106 €	Travel cost for meeting in Aachen
TOTAL DIRECT COSTS*		43.523 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 6 ULB (CFV)			
Work Package	**Item description**	**Amount**	**Explanations**
	Personnel costs		**)
	Subcontracting		
	Major cost item "Travel cost"	1.696 €	(1) Participation with my research group to two plenary Meetings of the Quasimodo projet: one in Aalborg (15-16/1/2008) and one in Aachen (2-4/6/2008) (2) Costs related to the visit of Pierre-Alain Reynier (15-18/12/2008) to work on the Hydac case study (WP5) and synthesis of controller with imperfect information (WP3)
TOTAL DIRECT COSTS*		1.696 €	

****) CFV/ULB:** So far, we have not used our budget for post-doc. We will hire, starting january 1st, Dr. Raphaella Gentilini. The work that has been done so far was mainly done by Prof. Jean-François Raskin who is fulll-time professor paid by ULB and by Dr. Pierre-Alain Reynier who was on a post-doc position in ULB paid by the French ministry of foreign affairs until september 2009. Dr. Reynier is now "Maître de conférence" at the University of Marseille.

The costs that we have imputed to the Quasimodo projects are related to the two workshop (one in Aalborg and one in Aachen). Also, Dr. Pierre-Alain Reynier has visited ULB from

Dec. 15 until Dec. 18 to work on Quasimodo research problems. His visit will be paid by the budget (but it may be the case that it appears only on the 2009 exercise as we are still waiting for the bills).

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 7 TERMA			
Work Package	**Item description**	**Amount**	**Explanations**
	Personnel costs	6.934 €	No hours registered on project in 2008 due to error in the setup of the project in the financial system. 3 employees has worked between 1 to 2 weeks on the project in 2008. One week for each has been included in the personal cost.
	Remaining direct costs	1.219 €	Travel cost for meeting in Aachen
TOTAL DIRECT COSTS*		8.153 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 8 CHESS			
Work Package	**Item description**	**Amount**	**Explanations**
5	Personnel costs	46.441 €	CHESS case study specifications, partner meetings & workshops
	Remaining direct costs	2.787 €	Travel expenses (meetings at Aalborg, Aachen and Saarbrucken)
TOTAL DIRECT COSTS*		49.228 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 9 Inchron			
Work Package	**Item description**	**Amount**	**Explanations**
5	Personnel costs	0€	
	Subcontracting		
	Remaining direct costs	0 €	
TOTAL DIRECT COSTS*		0 €	

Explanation of personnel costs, subcontracting and any major direct costs			
Beneficiary 10 HYDAC			
Work Package	**Item description**	**Amount**	**Explanations**
1,5	Personnel costs	20.948 €	case study description and support
	Travel Costs	761 €	Travel expenses (meetings at Aalborg, and Aachen)
TOTAL DIRECT COSTS*		21.709 €	

Cost-Budget followup

The following table shows the cost-budget followup for Quasimodo (the actual and percentual) spending of the *total budget (not EC contribution)* for Quasimodo. Except, as previously remarked about Chess, the spending is well aligned with the man-month effort and the fact the project is a third towards completion.

Contract no.	214755	Acronym:	Quasimodo			Date:	26. mar 2009				
Participants	Type of expenditure (as defined in budget)	Budget	Actual costs (EUR)				Pct. Spent				Remaining budget (EUR)
			Peiod 01.01 2008 to 31.12 2008	Period 2	Period 3	Total	Peiod 01.01 2008 to 31.12 2008	Year 2	Year 3	Total	
		e	a1	b1	c1	d1	a1/e	b1/e	c1/e	a1+b1+c1/e	e-d1
Partner 01	Total personmonth	46	15			15	33%				31
AAU	Personnel costs	206.224,35	63.022			63.022	31%				143.202
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	66.171,83	6.275			6.275	9%				59.897
	Indirect costs	163.437,70	41.578			41.578	25%				121.860
	Total costs	437.333,88	110.875			110.875	25%				326.459
	EC contribution										
Partner 02	Total personmonth	72	14			14	19%				58
ESI	Personnel costs	379.340,03	67.535			67.535	18%				311.805
	Subcontracting	4.500,00	0			0	0%				4.500
	Other direct costs	36.000,00	7.856			7.856	22%				28.144
	Indirect costs	249.204,02	45.234			45.234	18%				203.970
	Total costs	669.044,05	120.625			120.625	18%				548.419

Partner 03	Total personmonth	28	8			8	29%				20
CNRS	Personnel costs	97.500,50	45.094			45.094	46%				52.407
	Subcontracting	78.356,00	0			0	0%				78.356
	Other direct costs	11.072,00	500			500	5%				10.572
	Indirect costs	65.143,50	27.356			27.356	42%				37.788
	Total costs	252.072,00	72.950			72.950	29%				179.122
Partner 04	Total personmonth	28	11			11	39%				17
RWTH	Personnel costs	159.761,52	61.902			61.902	39%				97.860
	Subcontracting	1.500,00				-	0%				1.500
	Other direct costs	12.090,56	4.831			4.831	40%				7.260
	Indirect costs	103.111,24	40.039			40.039	39%				63.072
	Total costs	276.463,32	106.772			106.772	39%				169.691
Partner 05	Total personmonth	28	8			8	29%				20
UDS	Personnel costs	159.761,52	42.418			42.418	27%				117.344
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	12.090,56	1.106			1.106	9%				10.985
	Indirect costs	103.111,24	26.114			26.114	25%				76.997
	Total costs	276.463,32	69.638			69.638	25%				206.825

Partner 06	Total personmonth	28	0			0	0%				28
ULB	Personnel costs	144.532,02	0			0	0%				144.532
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	12.075,45	1.696			1.696	14%				10.379
	Indirect costs	93.964,48	1.017			1.017	1%				92.947
	Total costs	252.071,95	2.713			2.713	1%				249.359
Partner 07	Total personmonth	10	1			1	10%				9
Terma	Personnel costs	71.853,25	6.934			6.934	10%				64.919
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	10.500,00	1.219			1.219	12%				9.281
	Indirect costs	71.134,72	7.831			7.831	11%				63.304
	Total costs	154.987,97	15.984			15.984	10%				139.004
Partner 08	Total personmonth	10	8			8	80%				2
CHESS	Personnel costs	62.568,07	46.441			46.441	74%				16.127
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	10.500,00	2.787			2.787	27%				7.713
	Indirect costs	43.840,84	27.864			27.864	64%				15.977
	Total costs	118.408,91	77.092			77.092	65%				41.317

Partner 09	Total person-month	10	0			0	0%				10
INCHRON	Personnel costs	53.453,30	0			0	0%				53.453
	Subcontracting	1.500,00	0			0	0%				1.500
	Other direct costs	10.500,00	0			0	0%				10.500
	Indirect costs	38.371,98	0			0	0%				38.372
	Total costs	103.825,28	0			0	0%				103.825
Partner 10	Total person-month	10	3			3	30%				7
HYDAC	Personnel costs	70.859,75	20.948			20.948	30%				49.912
	Subcontracting	1.500,00				-	0%				1.500
	Other direct costs	10.500,00	761			761	7%				9.739
	Indirect costs	72.128,18	21.323			21.323	30%				50.805
	Total costs	154.987,94	43.032			43.032	28%				111.956
Total	Total person-month	270	68			68	25%				202
	Personnel costs	1.405.854,31	354.294	-	-	354.294	25%				1.051.560
	Subcontracting	94.856,00	-	-	-	-	0%				94.856
	Other direct costs	191.500,40	27.031	-	-	27.031	14%				164.469
	Indirect costs	1.003.447,90	238.356	-	-	238.356	24%				765.092
	Total costs	2.695.658,61	619.681			619.681	23%				2.075.978

The following table is required only for the funding schemes for Research for the benefit of SMEs

THE TRANSACTION

*Please provide a list of the actual cost incurred by the RTD performers during the performance of the work subcontracted to them. These costs refer only to the agreed '**Transaction**'.*

Name of RTD Performer	Number of person months	Personnel Costs	Durable equipment	Consumables	Computing	Overhead Costs	Other Costs	Total by RTD performer
TOTAL								

7. Financial statements – Form C and Summary financial report

Please submit a separate financial statement from each beneficiary (if Special Clause 10 applies to your Grant Agreement, please include a separate financial statement from each third party as well) together with a summary financial report which consolidates the claimed Community contribution of all the beneficiaries in an aggregate form, based on the information provided in Form C (Annex VI) by each beneficiary.

When applicable, certificates on financial statements shall be submitted by the concerned beneficiaries according to Article II.4.4 of the Grant Agreement.

IMPORTANT:

Form C varies with the funding scheme used. Please make sure that you use the correct form corresponding to your project. Templates for Form C are provided in Annex VI of the Grant Agreement. An example for collaborative projects is enclosed hereafter. A Web-based online tool for completing and submitting the forms C is under preparation. If you have to submit forms C before the tool becomes available, please ask your Commission project officer for an Excel version of the form.

If some beneficiaries in security research have two different rates of funding (part of the funding may reach 75% in reference with Article 33.1 of the EC rules for participation - REGULATION (EC) No 1906/2006) then two separate financial statements should be filled by the concerned beneficiaries and two lines should be entered for these beneficiaries in the summary financial report.

8. Certificates

List of Certificates which are due for this period, in accordance with Article II.4.4 of the Grant Agreement.

Beneficiary	Organisation short name	Certificate on the financial statements provided? yes / no	Any useful comment, in particular if a certificate is not provided
1		Yes	
2		no	
		no	Expenditure threshold not reached
Etc.			

A copy of each duly signed certificate on the financial statements (Form C) or on the methodology should be included in this section, according to the table above (signed originals to be sent in parallel by post).

9. Quasimodo Publications (as of February 1, 2009)

General

2008

Joost-Pieter Katoen, Perspectives in Probabilistic Verification, in: 2nd IEEE International Symposium on Theoretical Aspects of Software Engineering (TASE), pages 3-10, IEEE CS Press, 2008

Christel Baier and Joost-Pieter Katoen, Principles of Model Checking, MIT Press, 2008

WP1: Modelling and Specification

2008

Claus Thrane, Ulrich Fahrenberg and Kim G. Larsen, : Quantitative simulations of weighted transition systems, in: Proceedings of Nordic Workshop on Programming Theory, 2008

Hichem Boudali, Pepijn Crouzen, Boudewijn R. Haverkort, Matthias Kuntz and Marielle Stoelinga, Architectural dependability evaluation with Arcade, in: The 38th Annual IEEE/IFIP International Conference on Dependable Systems and Networks, DSN 2008, June 24-27, 2008, Anchorage, Alaska, USA, Proceedings, pages 512-521, IEEE Computer Society, 2008

Tingting Han, Joost-Pieter Katoen and Alexandru Mereacre, Compositional Modeling and Minimization of Time-inhomogeneous Markov Chains, in: Hybrid Systems: Computation and Control (HSCC), pages 244-258, Springer Verlag, 2008

Ulrich Fahrenberg and Kim G. Larsen, Discount-Optimal Infinite Runs in Priced Timed Automata., in: Proceedings of INFINITY 2008 10th International Workshop on Verification of Infinite-State Systems, 2008

Patricia Bouyer, Ulrich Fahrenberg, Kim G. Larsen, Nicolas Markey and Jiri Srba, Infinite Runs in Weighted Timed Automata with Energy Constraints, in: 6th International Conference on Formal Modelling and Analysis of Timed Systems (FORMATS'08), Saint-Malo, France, pages 33-47, Springer, 2008

Patricia Bouyer, Kim G. Larsen and Nicolas Markey, Model Checking One-clock Priced Timed Automata (2008), in: LMCS, 4:2:9

Patricia Bouyer, Nicolas Markey, Joel Ouaknine and James Worrell, On Expressiveness and Complexity in Real-time Model Checking, in: ICALP'08, Reykjavik, Iceland, pages 124-135, Springer, 2008

Pepijn Crouzen, Holger Hermanns and Lijun Zhang, On the Minimisation of Acyclic Models, in: CONCUR 2008 - Concurrency Theory, 19th International Conference, CONCUR 2008, Toronto, Canada, August 19-22, 2008. Proceedings, pages 295-309, Springer, 2008

Kim G. Larsen and Jacob I. Rasmussen, Optimal reachability for multi-priced timed

automata. (2008), in: Theoretical Computer Science, 390:2-3(197-213)

Nathalie Bertrand, Patricia Bouyer, Thomas Brihaye and Nicolas Markey, Quantitative Model-Checking of One-Clock Timed Automata under Probabilistic Semantics, in: QEST'08, Saint-Malo, France, pages 55-64, IEEE Computer Society Press, 2008

Benedikt Bollig, Carsten Kern, Joost-Pieter Katoen and Martin Leucker, Smyle: a Tool for Synthesizing Distributed Models from Scenarios by Learning, in: 19th International Conference on Concurrency Theory (CONCUR'08), pages 162-166, Springer, 2008

Joost-Pieter Katoen, M Bozzanol, G Burte, A Cimatti, M. le Coroller, Viet Yen Nguyen, T Noll and X Olive, System and Software Co-Engineering: Performance and Verification, in: ESA ADCCS Workshop, Noordwijk, The Netherlands, 2008

Mani Swaminathan, Martin Fraenzle and Joost-Pieter Katoen, The Surprising Robustness of (Closed) Timed Automata against Clock-Drift, in: 5th IFIP International Conference on Theoretical Computer Science (IFIP TCS), 2008

Taolue Chen, Tingting Han and Joost-Pieter Katoen, Time-Abstracting Bisimulation for Probabilistic Timed Automata, in: 2nd IEEE International Symposium on Theoretical Aspects of Software Engineering (TASE), pages 177-184, IEEE CS Press, 2008

WP2: Analysis

2009

Peter Boulychev, Tomas Chatain, Alexandre David and Kim G. Larsen, Playing Games with Timed Games, 2009

2008

Lijun Zhang, A Space-Efficient Probabilistic Simulation Algorithm, in: Concurrency Theory (CONCUR), pages 248-263, Springer, 2008

Christel Baier, Nathalie Bertrand, Patricia Bouyer, Thomas Brihaye and Marcus Größer, Almost-Sure Model Checking of Infinite Paths in One-Clock Timed Automata, in: Proceedings of the 23rd Annual IEEE Symposium on Logic in Computer Science (LICS'08), pages 217-226, {IEEE} Computer Society Press, 2008

Ulrich Fahrenberg and Kim G. Larsen, Discount-Optimal Infinite Runs in Priced Timed Automata., in: Proceedings of INFINITY 2008 10th International Workshop on Verification of Infinite-State Systems, 2008

Reza Pulungan and Holger Hermanns, Effective Minimization of Acyclic Phase-Type Representations, in: Analytical and Stochastic Modeling Techniques and Applications, 15th International Conference, ASMTA 2008, Nicosia, Cyprus, June 4-6, 2008, Proceedings, Nicosia, Cyprus, pages 128-143, Springer, 2008

Sebastian Kupferschmid, Jörg Hoffmann and Kim G. Larsen, Fast Directed Model Checking Via Russian Doll Abstraction., in: Proceedings of TACAS 2008, 2008

Lijun Zhang, Holger Hermanns, Friedrich Eisenbrand and David N. Jansen, Flow Faster: Efficient Decision Algorithms for Probabilistic Simulations (2008), in: Special Issue on TACAS 2007, Logical Method in Computer Science (LMCS)

Joost-Pieter Katoen and Alexandru Mereacre, Model Checking HML On Piecewise-Constant Inhomogeneous Markov Chains, in: FORMATS'08, Springer-Verlag, 2008

Patricia Bouyer, Kim G. Larsen and Nicolas Markey, Model Checking One-clock Priced Timed Automata (2008), in: LMCS, 4:2:9

Marcin Jurdzi{\'n}ski, François Laroussinie and Jeremy Sproston, Model Checking Probabilistic Timed Automata with One or Two Clocks (2008), in: Logical Methods in Computer Science, 4:3:12

Kim G. Larsen and Jacob I. Rasmussen, Optimal reachability for multi-priced timed automata. (2008), in: Theoretical Computer Science, 390:2-3(197-213)

Alexandre David, Piotr Kordy, Kim G. Larsen and Jan Willen Polderman, Practical Robustness Analysis of Timed Automata, 2008

Holger Hermanns, Björn Wachter and Lijun Zhang, Probabilistic CEGAR, in: 20th International Conference on Computer Aided Verification (CAV), pages 162-175, Springer, 2008

Nathalie Bertrand, Patricia Bouyer, Thomas Brihaye and Nicolas Markey, Quantitative Model-Checking of One-Clock Timed Automata under Probabilistic Semantics, in: QEST'08, Saint-Malo, France, pages 55-64, IEEE Computer Society Press, 2008

Berteun Damman, Tingting Han and Joost-Pieter Katoen, Regular Expressions for PCTL Counterexamples, in: Quantitative Evaluation of Systems (QEST), IEEE CS Press, 2008

Reza Pulungan and Holger Hermanns, The Minimal Representation of the Maximum of Erlang Distributions, in: Proceedings 14th GI/ITG Conference on Measurement, Modelling and Evaluation of Computer and Communication Systems (MMB 2008), March 31 - April 2, 2008, Dortmund, Germany, GI Fachausschuss 3.2 / ITG Fachausschuss 6.5, Dortmund, Germany, pages 207-222, VDE Verlag, 2008

Lijun Zhang, Holger Hermanns, Ernst Moritz Hahn and Björn Wachter, Time-Bounded Model Checking of Infinite-State Continuous-Time Markov Chains, in: Application of Concurrency to System Design (ACSD) 2009, 2008

WP3: Implementation

2009

Alexandre David, Jacob I. Rasmussen, Kim G. Larsen and Arne Skou, Model-based Framework for Schedulability Analysis Using UPPAAL 4.1, Taylor ad Francis, 2009

Franck Cassez, J. J. Jessen, Kim G. Larsen, Jean-François Raskin and Pierre-Alain Reynier, Robust and Optimal Contorllers - An Industrial Case Study, in: To appear in Proceedings of HSCC'09, 2009

Alexandre David, Kim G. Larsen and Didier Lime, UPPAAL-TIGA 2009: Towards Realizable Strategies, 2009

2008

Christel Baier, Nathalie Bertrand, Patricia Bouyer, Thomas Brihaye and Marcus Größer, Almost-Sure Model Checking of Infinite Paths in One-Clock Timed Automata, in:

Proceedings of the 23rd Annual IEEE Symposium on Logic in Computer Science (LICS'08), pages 217-226, {IEEE} Computer Society Press, 2008

Patricia Bouyer, Thomas Brihaye, Marcin Jurdzi{\'n}ski, Ranko Lazi{\'c} and Micha{þ} Rutkowski, Average-Price and Reachability-Price Games on Hybrid Automata with Strong Resets, in: Proceedings of the 6th International Conference on Formal Modelling and Analysis of Timed Systems (FORMATS'08), pages 63-77, Springer, 2008

Franck Cassez and Nicolas Markey, Contrôle des systèmes temporisés, Invited lecture, 2008

S. Akshay, Benedikt Bollig, Paul Gastin, Madhavan Mukund and K. Narayan Kumar, Distributed Timed Automata with Independently Evolving Clocks, in: Proceedings of the 19th International Conference on Concurrency Theory (CONCUR'08), pages 82-97, Springer, 2008

Patricia Bouyer, Ed Brinksma and Kim G. Larsen, Optimal Infinite Scheduling for Multi-Priced Timed Automata (2008), in: Formal Methods in System Design, 32:1(2-23)

Alexandre David, Piotr Kordy, Kim G. Larsen and Jan Willen Polderman, Practical Robustness Analysis of Timed Automata, 2008

Nathalie Bertrand, Patricia Bouyer, Thomas Brihaye and Nicolas Markey, Quantitative Model-Checking of One-Clock Timed Automata under Probabilistic Semantics, in: QEST'08, Saint-Malo, France, pages 55-64, IEEE Computer Society Press, 2008

Patricia Bouyer, Nicolas Markey and Pierre-Alain Reynier, Robust Analysis of Timed Automata via Channel Machines, in: Proceedings of the 11th International Conference on Foundations of Software Science and Computation Structures (FoSSaCS'08), pages 157-171, Springer, 2008

Martin De Wulf, Laurent Doyen, Nicolas Markey and Jean-François Raskin, Robust Safety of Timed Automata (2008), in: Formal Methods in Computer Design, 33:1-3(45-84)

Mani Swaminathan, Martin Fraenzle and Joost-Pieter Katoen, The Surprising Robustness of (Closed) Timed Automata against Clock-Drift, in: 5th IFIP International Conference on Theoretical Computer Science (IFIP TCS), 2008

WP4: Testing

2008

Alexandre David, Shuhao Li, Brian Nielsen and Kim G. Larsen, A Game-Theoretic Approach to Real-Time System Testing, in: DATE, pages 486-491, 2008

Shuhao Li, Alexandre David, Kim G. Larsen and Brian Nielsen, Cooperative Testing of Uncontrollable Timed Systems, in: Fourth Workshop on Model-Based Testing (MBT'08), 2008

Jan Tretmans, Model based testing with labelled transition systems, in: Formal Methods and Testing, pages 1-38, Springer-Verlag, 2008

Jan Tretmans and Julien Schmaltz, On conformance testing for timed systems, in: 6th International Conference on Formal Modelling and Analysis of Timed Systems (FORMATS'08), St Malo, France, pages 248-263, Springer, 2008

Henrik Bohnenkamp and Marielle Stoelinga, Quantitative Testing, in: Proc. EMSOFT 2008, ACM, 2008

Anders Hessel, Marius Mikucionis, Brian Nielsen, Paul Pettersson, Arne Skou and Kim G. Larsen, Testing Real-Time Systems Using UPPAAL, LNCS, volume 4949, 2008

WP5: Case Studies, Tools, Dissemination and Exploitation

2009

Franck Cassez, J. J. Jessen, Kim G. Larsen, Jean-François Raskin and Pierre-Alain Reynier, Robust and Optimal Contorllers - An Industrial Case Study, in: To appear in Proceedings of HSCC'09, 2009

2008

Lijun Zhang, A Space-Efficient Probabilistic Simulation Algorithm, in: Concurrency Theory (CONCUR), pages 248-263, Springer, 2008

Jonathan Bogdoll, Holger Hermanns and Lijun Zhang, An Experimental Evaluation of Probabilistic Simulation, in: 28th IFIP WG 6.1 International Conference on Formal Techniques for Networked and Distributed Systems (FORTE), pages 37-52, Springer, 2008

David N. Jansen, Joost-Pieter Katoen, Marcel Oldenkamp, Marielle Stoelinga and Ivan S. Zapreev, How fast and fat is your probabilistic model checker? An experimental comparison, in: Proceedings of the 3rd Haifa Verification Conference (HVC 2007), Haifa, Israel, pages 69-85, Springer, 2008

Viet Yen Nguyen and Theo C. Ruys, Incremental Hashing for SPIN, in: Proceedings 15th International SPIN Workshop on Model Checking of Software, 2008

Pepijn Crouzen, Holger Hermanns and Lijun Zhang, On the Minimisation of Acyclic Models, in: CONCUR 2008 - Concurrency Theory, 19th International Conference, CONCUR 2008, Toronto, Canada, August 19-22, 2008. Proceedings, pages 295-309, Springer, 2008

Holger Hermanns, Björn Wachter and Lijun Zhang, Probabilistic CEGAR, in: 20th International Conference on Computer Aided Verification (CAV), pages 162-175, Springer, 2008

Lijun Zhang, Holger Hermanns, Ernst Moritz Hahn and Björn Wachter, Time-Bounded Model Checking of Infinite-State Continuous-Time Markov Chains, in: Application of Concurrency to System Design (ACSD) 2009, 2008