Testing of Event-Triggered Real-time Systems - TETReS

Final 2002 report
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ARTES project 9905-11

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1 Introduction

This document is the final report (2002) for the project "Testing of Event-Triggered Real-time Systems" (TETReS) at University of Skövde. Two problem areas are addressed in the project: (1) improving testability of event-triggered real-time systems by applying constraints on the application behavior, and (2) automated test-case generation and execution for such systems. The results from (1) provides strong support for the hypothesis. One of the main results is a formal model that will be used for validating the hypothesis further. The results from (2) include a framework for automated timeliness testing of dynamic real-time systems, and describe the required experiments for validating it. These results are addressed in two thesis proposals (appended to this document). Further, both of the participating Ph.D. students have completed more than 2/3 of their planned course credits.

2 Project plan summary

The project consists of two sub-projects with individual plans and objectives.

A Plans for 2002

- A(1) Development of a strategy for evaluation and enforcement of constraints on the execution environment.
- A(2) Development of initial test case generation and execution strategies.

B Plans for previous years

- B(1) Analysis of current methods for improving software testability. The analysis is available since December 2000.

B(2) Analysis of current test case selection techniques. The analysis is available since December 2000.

B(1)+(2) Write-up of Intermediate reports and updated specification for each of the sub-projects. These are available since March, 2002.

C Plans for future years

C(1) Implementation of enforcement mechanism. Solutions to application specific problems. Enforcement mechanisms and solutions to application specific problems integrated into DeeDS.

C(2) Development of test case generation and selection tools. Prototypes of automated test tools for generating, selecting, and analyzing the quality of test cases.

3 Achieved results

Regarding the fist project we have achieved results that strongly supports the hypothesis in previous work by Mellin (1998), including the upper bound on the number of execution orders. These results have been presented at RTCSA'02. We have proposed a formal model that can be used for (*i*) specification of enforcement mechanisms, and (*ii*) experimental validation of the results. We are also planning to submit a paper on the aformentioned formal model. A paper that emphasizes the research problems of the project has been presented at the EuroStar Industrial conference on testing.

Regarding the second project a framework for automatic test-case execution in a transaction-based setting and requirements on test case generation for dynamic real-time systems has been published at RTCSA'02. A specification model for test case generation is adopted and refined to capture the non-deterministic temporal behavior of dynamically scheduled real-time systems. Suggestion for such refined specification model and initial testing criteria are presented in the thesis proposal. Currently, the proposed set of test selection criteria for testing timeliness and robustness are evaluated. The testing criteria remain to be validated and integrated in a complete framework for test-case selection and execution. A prototype tool for comparing and evaluating test strategies and architectural support for automatic testing is being implemented.

4 Deviation from plan

The only deviation from the plan is that there is a three-month delay of the write-up of the intermediate reports and the thesis proposals. The reports where delivered in March, 2002 instead of December, 2002. The thesis proposals where delivered in February, 2003 instead of December, 2002. A contributing factor to the delay is that 2/3 of Ph.D. course credits have been completed. Appendix B contains a more detailed description of the Ph.D. students' activities during the first part of the project. Both of the participating Ph.D. students aim to go directly to a Ph.D. degree with no intermediate Lic. degree. Financial support for the remaining time in this project is guaranteed through FLEXCON for one full time Ph.D. student. The plan is to divide this support equally between Robert Nilsson and Birgitta Lindström and seek further financial support elsewhere.

5 External co-operation

This section presents external activities towards our industrial partner and other research groups.

5.1 Industrial co-operation

Our industrial partner in this project is Enea Test, with over 50 industrial testing consultants, a part of Enea Realtime AB (former Industrial Systems division of Enea Data AB). The customers of Enea Test cover a large proportion of the Swedish real-time industry.

Our reference person at Enea Test, Mats Grindal, is now working 60% as an industrial Ph.D. student in our research group. His experience and insight into current industry practice in testing of real-time systems gives an important contribution to our project. The research problem Mats Grindal addresses how to apply our results to currently used, unconstrained real-time systems. Enea's broad range of contacts with the industry provides an excellent opportunity to transfer the technology produced by our project into industry.

Examples of the cooperation between Enea Test and Skövde is that Robert Nilsson and Birgitta Lindström have participated in a seminar at Enea where a new test process, developed by Enea, was presented and discussed. All of the project members participated in an industrial seminar on testing where Mats Grindal gave a presentation that combined his industrial experience with results from our research in Skövde. Another example is an article that was published at EuroSTAR in November 2002. This article is written by Mats Grindal and Birgitta Lindström and is based on the presentation from the industrial seminar. Mats Grindal and Birgitta Lindström have also given a presentation of TETReS at the seminar "Västsvensk fordonsdag" in Gothenburg.

5.2 Other external co-operation

Mats Grindal and Birgitta Lindström have performed an experimental evaluation of different combination strategies that can be used to select test cases. The evaluation will be presented in a technical report in spring, 2003. We also plan to submit an article on this subject in 2003.

The formal specifications used for test-case generation within TETReS have been inspired by the UPPAAL project. Therefore, a course on UPPAAL was given at Skövde by professors from Uppsala. An idea that came from this activity is to exploit formal specifications to support generation of ECA-based applications automatically. An initial study was performed by Ericsson (2002) and is now being continued as an MSc project. This approach increases analyzability of such applications and can avoid problems such as hidden cascade triggering in ECA-rule sets. The generated applications should comply with proposed constraints for testability and fit in to the framework for automated testing. As a result of this work, an application for funding from CUGS has been prepared and filed. Furthermore, the UPPAAL tool has been included in our undergraduate education.

Appendix A : Publications

Lindström B. (2000), "Methods for increasing software testability", Masters thesis, University of Skövde, HS-IDA-MD-00-017.

Nilsson R.(2000), "Automatic selective test case generation methods for real-time systems", Masters thesis, University of Skövde, HS-IDA-MD-00-010.

Grindal, M. and Lindström, B. (2002). "Challenges in Testing Real-Time Systems", In *Proceedings of 10th International Conference on Software Testing Analysis Review (EuroSTAR'02)*, Edinburgh, Scotland. CD-ROM.

Lindström B., Mellin J., and Andler S.F. (2002), "Testability of Dynamic Real-Time Systems", *The 8th International Conference on Real-Time Computing Systems and Applications (RTCSA'02).*

Nilsson R., Andler S.F., and Mellin J. (2002), "Towards a Framework for Automated Testing of Transaction-based Real-Time Systems", *The 8th International Conference on Real-Time Computing Systems and Applications (RTCSA'02).*

Selected previous publications

Mellin J. (1998), "Supporting system level testing of applications by active real-time database systems", *Proceedings of the second International Workshop on Active, Real-Time, and Temporal Database Systems*, LNCS 1553, Springer-Verlag.

Birgisson R., Mellin J., and Andler S. F., (1999), "Bounds on test effort for event-triggered systems", *The 6th International Conference on Real-Time Computing Systems and Applications (RTCSA'99).*

Supportive publications

Ericsson, A. (2002), "Deriving ECA-rules from timed-automata specifications.", Final year project, University of Skövde, HS-IDA-EA-02-201

Mellin, J. and Andler, S.F., (2002), "A Formalised Schema for Event Composition", *The 8th International Conference on Real-Time Computing Systems and Applications (RTCSA'02)*

Appendix B: Activities

Year	Course	Credits	
2000		BL	RN
	Distributed real-time systems	6	6
	Database systems	6	6
	Logics	6	6
	Connectionism and AI		6
	ECTS 2000 - Summer school	1	1
Sum, 2000		19	25
2001			
	Connectionism and AI	6	
	Scientific methodology	6	6
	Software testing	3	3
	Active real-time databases	3	3
	HW/SW codesign		3
Sum, 2001		18	15
2002			
	Specification-based testing	3	3
	Scientific communication	5	5
	UPPAAL	3	3
	Pedagogy	5	5
	Safety Critical computer control systems	2	2
Sum, 2002		18	18
Total		**55**	**58**

Table 1: Distribution of work Jan, 2000 - December, 2002.

At 80% of full-time PhD studies, 16 course-credits per year, 48 credits should have been completed in December 2002. Instead, a total of 55 and 58 is completed respectively. Not all credits have been registered yet but all work is finished and approved. Moreover, part of the time for research work has been spent on other activities, such as presentation on Västsvensk Fordonsdag at Volvo in Gothenburgh and on writing or reviewing articles. Still, both of the project participants where able to deliver their thesis proposals in February, 2003.