Hardware/Software Codesign of Real-Time Systems

Status report for the ARTES evaluation

1. Introduction and Objectives

This project deals with system-level design methods and tools for mixed hardware/software systems, with special emphasis on real-time issues. The project has been conducted at the Embedded Systems Laboratory (ESLAB), which is part of the Center for Embedded Systems Engineering (CESE) at Linköping University, in close cooperation with Volvo Technological Development (TD) and Saab Dynamics AB. The project has been planed for two + two years for a PhD thesis work by Paul Pop.

The main objective of the project is to develop a system design environment which consists of a set of integrated design methods and tools to allow designers to quickly explore the design space and to produce optimized implementations. The main application area of the developed environment is embedded real-time systems consisting of software and hardware components.

The basic idea of the design environment is that it should allow designers to start the design process with a system specification which does not prescribe the implementation details, such as what to be implemented in hardware and what to be implemented in software. The system specification will then be mapped into a hardware/software architecture model to allow efficient analysis of design parameters. The analysis results will be used to guide the selection or improvement of the implementation architecture and parameters.

2. Achievement up till Now and Scientific Merits

During the period from 980301 to now, we have concentrated on several specific aspects related to scheduling and communication in safety critical hard real-time systems for automotive applications. This direction has been decided upon as a result of our close cooperation with the industrial partner at Volvo TD.

The main research work and results of this period are:

(1) Static scheduling of mixed control/data-flow systems implemented on distributed architectures.

In order to capture both the data-flow and the control aspects of a given application, a conditional process graph representation has been defined. Algorithms for static, time/driven scheduling of conditional process graphs on distributed systems have been developed and implemented. These algorithms can be used to estimate system performance during design space exploration and for synthesis of the final implementation of embedded real-time systems. Our main contribution in this area is the development of an efficient static scheduling technique, taking into account both data and control dependency, with end-to-end constraints.

(2) Scheduling and communication synthesis with TTP-based communication.

The Time-Triggered Protocol (TTP) is becoming more and more accepted as the communication infrastructure of safety-critical automotive applications. In this context we have extended our research in the following directions:

- We have adapted our scheduling algorithm considering TTP as the particular protocol for inter-processor communication. We have taken into consideration the impact of the protocol on the timing of message passing and, by this, on the scheduling of processes.

- We have developed algorithms in order to optimize the parameters of the protocol (e.g. order and size of slots) such that specific requirements and constraints imposed by the application are met.
- We have investigated schedulability aspects of applications implemented with priority-based preemptive scheduling on top of a TTP-based communication support. In this context, we have found solutions for schedulability analysis and have developed algorithms for optimization of the protocol parameters. Both analysis and optimization are based on four alternatives for message scheduling which we have proposed.

All of these results have been published in international conferences in the codesign and real-time system communities.

3. Industrial Cooperation and Exploitation

The main industrial partner which participates actively in the project is Volvo Technological Development. Saab Dynamics AB has also been involved in the formulation of the research direction and identification of the main research issues of the project.

The industrial partners will participate in the case studies and evaluations of results. One design case, an adaptive cruise controller, has already been identified with Volvo TD. It is also expected that the developed design methods and tools will be tested by the industrial partners in the next phases of the project.

Regular meetings have been held with the industrial partners to discuss the project activities, disseminate produced results, and get their feedback. This will be continued for the rest of the project.

4. Mobility Activities

The PhD student working on the project, Paul Pop, made a two-week visit to Volvo Technological Development at Göteborg in the Autumn of 1998. The visit has led to a better understanding of the industrial codesign process and the need for tools for the earlier design activities. A design case has also been identified as a result of the visit.

A second and longer visit has also been planned.

5. Publications

P. Pop, P. Eles, and Z. Peng, “An Improved Scheduling Technique for Time-Triggered Embedded Systems,” Proc. Euromicro’99 Workshop on Digital System Design: Architectures, Methods and Tools, Milan, Italy, Sept. 8-10, 1999.

P. Pop, P. Eles, and Z. Peng, “Communication Scheduling for Time-Triggered Systems,” Work-in-progress presentation at 11th Euromicro Workshop on Real-Time Systems, York, England, June 9-11, 1999.

P. Pop, P. Eles, and Z. Peng, “Scheduling with Optimized Communication for Time-Triggered Embedded Systems,” Proc. 7th International Workshop on Hardware/Software Codesign (CODES), Rome, Italy, May 3-5, 1999.

P. Eles, K. Kuchcinski, Z. Peng, A. Doboli and P. Pop, “Process Scheduling for Performance Estimation and Synthesis of Hardware/Software Systems,” Proc. Euromicro’98 Workshop on Digital System Design: Architectures, Methods and Tools, Västerås, Aug. 25-27, 1998, pp. 168-175.

P. Pop, P. Eles, and Z. Peng, “Scheduling Driven Partitioning of Heterogeneous Embedded Systems,” Proc. 7th Swedish Workshop on Computer Systems Architecture, Göteborg, June 3-5, 1998, pp. 99-102.

P. Eles, K. Kuchcinski, Z. Peng, A. Doboli and P. Pop, “Scheduling of Conditional Process Graphs for the Synthesis of Embedded Systems,” Proc. Design, Automation and Test in Europe (DATE’98), Paris, France, Feb. 23-26, 1998, pp. 132-138.

NOTE: All publications are available via http://www.ida.liu.se/~eslab/rts1.html

6. Project Plan for the Next Period

Paul Pop is expected to present his Licentiates thesis in the Spring of 2000. The main tasks to be executed up till then are:

- Continue the implementation and refinement work of the scheduling and performance analysis algorithms for task allocation. This has already been started and the preliminary results show that our algorithms produce good results.
- Develop rules to use the performance analysis result to manually modify the architecture.

The development of the whole codesign environment including the scheduling and analysis algorithms as well as architecture selection and synthesis techniques will be Paul Pop's PhD thesis topic.