

Proposal to ARTES

Flexible Reliable Timing Constraints

Gerhard Fohler
Mälardalens University
Box 883, 721 23 Västerås
gerhard.fohler@mdh.se

Industrial Partner:

Mikael Strömberg
MECEL AB

International Partner:

Prof Krithi Ramamritham
University of Massachusetts/ IIT Bombay

1 Summary

The goal of the proposed research is to develop methods for the derivation, specification, and run-time execution of activities with timing constraints, which exploit inherent flexibility in temporal demands, e.g., on application level, instead of *overconstraining* specifications. We propose to use *flexible timing constraints*, which express feasibility information of activities rather than numbers demanded by common system models and scheduling algorithms. These will be scheduled by *novel offline algorithms*, which are capable of exploiting the expressed flexibility, while maintaining *reliability* requirements.

2 Problem Statement

The main concern with respect to temporal behavior of a real-time system is meeting the timing relations between input and output from and to the environment, respectively. Timing constraints such as period and deadline meet demands of system models and in particular scheduling algorithms rather than application level requirements. Instead of focussing on application demands, timing constraints are determined to suit task models mandated by system operation.

Many real-world industrial applications, e.g., control applications, have timing requirements which cannot be expressed by deadlines and periods or which restrict the system if expressed by standard timing constraints. Only few tasks have “natural” periods and deadlines. Most are only derived during system design in an iterative process: they are artifacts. Often, several settings for deadline and period may be feasible, but only one can be selected: the specification becomes *overconstrained*. In addition, the knowledge about original requirements and their inherent flexibility is abandoned and no longer available to subsequent design and runtime phases. The decomposition of end-to-end deadlines in distributed systems, for example, results in constraints for tasks on individual nodes with no information about other tasks and overall deadlines. Only when the entire design is completed, can an incorrect selection be detected, e.g., by a failed scheduling attempt.

Most current scheduling techniques are designed to handle constraints expressed on the level of periods and deadlines. Consequently, they cannot exploit extra flexibility in temporal demands efficiently. One particular restriction is the assumption of timing constraints being *static*, i.e., they are the same and stay fixed for all instances of an activity. This prevents solving timing problems by changing the set of timing constraints for single instances, e.g., to avoid collisions with other periodic or aperiodic activities, or rearranging subtask deadlines.

No temporal guarantees can be given if the system does not provide certain reliability: deadlines are at risk if simple faults cannot be tolerated and lead to failures. Special attention has to be given to the impact of increased temporal flexibility on reliability, e.g., with respect to fault tolerance methods such as replica determinism.

3 Main Ideas

We propose to investigate into *flexible timing constraints*, which help to overcome the above stated problems. Instead of using numbers to constrain tasks, such as for period and deadline, these represent information about the *feasibility* of system activities: Timing entities, i.e., functional units whose execution is temporally constrained, are given feasibility functions describing the temporal relations on the unit's input and output. Instances of timing entities and constraints can be tested by the feasibility function. In the case of repeating or periodic entities, the derived constraints can either be constant for all instances or varying with each instance.

We envision *decomposition* of the proposed flexible timing constraints: Given a timing entity composed of subentities and a feasibility function, a set of feasible timing constraints for the subentities can be instantiated, keeping information about flexibility. Starting from application level demands on input and output of system services, an iterative design process refines until a scheduling algorithm can process the timing constraints.

While knowledge of flexibility in temporal constraints facilitates the design process, it can be fully exploited when taken into account during scheduling: Artifacts created during design can be changed, e.g., to change subtask deadlines, within the flexibility provided during scheduling, instead of requiring re-

design and rescheduling. New scheduling methods will have impact on runtime complexity and system reliability. We will investigate into several directions for scheduling of timing entities and flexible timing constraints and analyze each for such tradeoffs.

In systems where standard scheduling algorithms with standard timing constraints are mandated, the scheduler can use the knowledge about artifacts, their constraints, and alternatives to pinpoint candidates for change, instead of a “blind” redesign. Another direction will be to develop algorithms which work without the “bottleneck” of standard constraints by directly scheduling timing entities with full exploitation of their flexibility. These will allow for varying constraints for different instances. As mentioned above, we will study the effect of added flexibility on system properties, in particular on reliability for each of the new scheduling methods.

4 Expected Results and Impact

The results of our research will be methods for derivation, specification and scheduling to exploit temporal flexibility in real-time systems while maintaining demands on reliability.

Mecel has expressed demand for the proposed research and will provide applications to be studied for their temporal constraints and flexibility. As a case study, a specification method will be provided and an appropriate scheduler selected and modified to suit the BASEMENT architecture.

5 Project Plan

This project will be conducted by two Ph.D. students with 20% of department duties and supervised by Gerhard Fohler and Prof. Krithi Ramamritham. The project will span over a period of 2.5+2.5 years.

Year	Phase	Activity
1	1	Analysis of industrial application for constraints and system requirements
1.5	2	Definition of requirements on methods
2	3	Analysis of scheduling methods
3	4	Development of specification method and design process
3	5	Modifications to existing and new scheduling algorithms
4	6	Implementation of tool support
4.5	7	Analysis and tuning of methods
5	8	Deployment

6 Preliminary Budget

We project the total project budget to be comprised of funding for

- Two Ph.D. student salaries for 2.5 + 2.5 years, considering departmental duties
- supervision cost
 - Gerhard Fohler, salary, 20%
 - Prof. Ramamritham, mobility, remuneration, 2 weeks/year
- research stays for Ph.D. students at international institution (2-3 months)
- conference travel for presentation of results
- a 20% department overhead is added to the above listed items

7 Related Research

The issue of timing constraints, their origins and use has been discussed in [Ramamritham:]. The crea-

tion of artifacts and constraints in the design process with respect to predictability was addressed in [Stankovic:90].

Early versions of flexible timing constraints have been proposed in [Fohler:97].

Gerber et. al. have studied relative timing constraints [Gerber:95b] and design based on end-to-end deadlines [Gerber:95]. Cheng and Agrawala [Cheng:97] developed a scheduling algorithm for relative timing constraints.

[Seto:97] presented a method to derive periods for rate monotonic scheduling from a control application.

[Fohler:94] presented the modification of a static scheduler to include constraints specified in RTL [Jah86:].

Issues of incremental schedule construction and offline scheduling to meet general requirements are currently studied in the ARTES projects "Incremental, iterative schedule construction", and "Identification of Complexity-Reduction Techniques for Optimal Scheduling in Embedded Distributed Real-Time Systems".

8 Relation to Profile and Industry

Our proposed research aims at solving real-time problems meeting industrial demands. It will be carried out in co-operation with the industrial partner. The process will provide us with insights in concrete, application specific, real-time engineering practices and broaden the scientific foundation for industry.

We expect to learn how to specify and design real-world real-time systems by analyzing the actual problems, their requirements and used industrial practice, and by providing solutions and research to meet the encountered demands.

The use of flexible timing constraints acknowledges the need of specifications meeting industrial application demand rather than that of target system and scheduling algorithm. It will enable designers to focus on application constraints and design, reduce design cycles, and provide more general and efficient scheduling methods.

9 Context

9.1 The research group

The proposed research will be carried out at the Computer Engineering Department (IDt) at Mälardalen University, Västerås in co-operation with Mecel AB, Gothenburg as industrial partner and Prof. Ramamirtham, University of Massachusetts/IIT Bombay as external supervisor.

Real-time systems research was established at MdH around 1990 by three persons as a glue between academia and industry. It has since then been the most active and fast growing research area, as well as a strong educational profile, at MdH. The real-time research at MdH is supported by a number of regional and national authorities, foundations and companies. As a result, real-time systems has been identified (by the university board) as the research area of highest priority at MdH. It has grown to approximately 40 persons providing 500 full time student equivalents.

9.2 Complimentary activities

The SALSART tool suite for distributed schedule design and analysis, currently being developed, will be used to assist the development of the proposed research and methods. A number of master thesis projects both at IDt and Mecel will help with implementations.

The ARTES funded project, "Incremental, iterative schedule construction", currently carried out at IDt will provide help for the development of schedules and constraints.

Our project will interact closely with the ARTES funded project, "Identification of Complexity-Reduction Techniques for Optimal Scheduling in Embedded Distributed Real-Time Systems", currently carried out at Chalmers University under supervision of Jan Jonsson

9.3 International co-operation

Prof Krithi Ramamritham from University of Massachusetts/ IIT Bombay will be a partner in the project and a student co-supervisor. His participation will be 2 weeks/year.

Prof Krithi Ramamritham
Department of Computer Science
Umass
Amherst, MA 01002
krithi@cs.umass.edu

9.4 Industrial co-operation

Mecel AB has a group consisting of around 10 persons working with the design of distributed real-time system in automotive applications. Mikael Strömberg leads this group.

Mikael.Stromberg
Mecel AB
Box 140 44
S-400 20 Göteborg
mikael.stromberg@mecel.se

10 References

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11 Appendices

- Appendix A: C.V. of Gerhard Fohler
- Appendix B: Support letter Prof Ramamritham
- Appendix B: Support letter Mecel

Appendix A
C.V. of Gerhard Fohler

Appendix B
Support letter Prof Ramamritham

Appendix C
Support letter Mecel