Embedded Databases for Embedded Real-Time Systems

- COMET: COMponent-based Embedded real-Time database systems

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2nd year report (2002)

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Introduction

This is the 2002 project report for the COMET project, component-based embedded database systems.

The goal of this research project is to bridge the gap between embedded systems, real-time systems and database systems, with a particular focus on the software development tools. Significant amount of research has focused on how to incorporate database functionality into real-time systems without jeopardizing timeliness and how to incorporate real-time behavior into embedded systems. However, research for embedded databases used in embedded real-time systems, which explicitly address (i) the development and design process, and (ii) the limited amount of resources in embedded systems is sparse. This type of research inherits the challenges from component-based software engineering, embedded systems, and real-time systems. Further, this research explicitly addresses system resource demand for the system in the design of the embedded database in order to minimize system resource usage.

The goal is to build an experimental research platform for building embedded databases for embedded real-time systems. At a high-level, the platform consists of two parts. First, we intend to develop a component library, which holds a set of components that can be used when building an embedded database. Initially, we will develop a set of components that deal with concurrency control, scheduling, and main-memory techniques. At the next step, we develop tools that, based on the application requirements, will support the designer when building an embedded database using these components. More importantly, we want to develop application tools and techniques that support the designer in the composition and tailoring of an embedded database for a specific system using the developed components, and where the application requirements are given as an input. Further, we want to provide support to the designer when analysing the total system resource demand of the composed embedded database system; and help the designer by recommending components and methods if multiple components can be used, based on the application requirements.

Summary of project plan

In the project plan we identified the following major phases of the projects.

i. Introduction to the area for the new doctoral candidates. Given the little research done in the area of embedded databases for embedded systems, one should study the state-of-the-art in closely related disciplines, i.e., in our case they are component-based development techniques appropriate for real-time systems, embedded database systems, and real-time database systems.
   Deliverable: A state-of-the-art survey, and a detailed project plan (specification of remaining years)
ii. Study application scenarios and formulate the application requirements. Based on the identified application requirements, select appropriate techniques for resource allocation and concurrency control that exist and should be part of the component library.
   Deliverable: A design document of the component library.
iii. Develop a technique for specifying real-time and database component characteristics and their resource demands. Implementation of the chosen techniques/algorithms that were chosen in previous phase.

Deliverable: Component library consisting of techniques for resource allocation and concurrency control.

iv. Develop a technique, e.g. a rule language, for specifying how components can be combined; this includes also identifying what type of distinct dependencies between components that needs to be represented. Implementation of a tool that supports the technique.
Deliverable: An article submitted to workshop or conference presenting the proposed technique.

v. Implementation of a test prototype using an application scenario provided by the industrial partners. This is followed up by an in-depth evaluation and benchmarking of the system, an evaluation of the architectural design, and identification of the benefits and deficiencies of the design tools.
Deliverable: Two articles submitted to conferences, or one long article submitted to journal for publication. A document proposing changes that should be done to the tools and the component library.

vi. Refinement of tools and components. Write up of theses.
Deliverable: Updated software tool. PhD theses.

Achieved results

During the **1st year** the following was achieved: The first phase was completed, and an extensive survey, covering relevant database systems (embedded, real-time, component) from both industrial and research point of view, and research efforts on using components in real-time systems, has been written (see [1]). In the second phase, the doctoral students made an industrial stay for two weeks at Volvo Construction Equipment Components AB, which they found valuable to understand future needs as well as shortcomings in existing systems. This resulted in a case study report (see [2]) that documents application scenarios and their specific demands on data management. The development of a database, called COMET, has started and we have performed an initial design of COMET, identifying types of database components, different types of aspect (application, composition, run-time). This has resulted in a report (see [3]). The approach taken in the project is to achieve customisation by composition using components and aspects. A component is the result of functional decomposition, such that components have strong cohesion. Aspects are used for managing crosscutting issues (inter-component), e.g., temporal behavior of system, security etc. In conclusion, we consider the first two phases of the project to be complete (although we do expect to refine our architecture as we develop COMET).

During the 2nd year of the project, we have achieved the following:

- The development of the COMET architecture, and also made an implementation of the first set of components using the component model described below.
- The concept of database pointers, to achieve predictable and efficient access to individual data elements within a real-time database.
- A new method for building real-time systems using aspects and components has been established. This method is called aspectual component-based real-time system development (ACCORD). ACCORD supports the notion of aspects and components in real-time systems by allowing decomposition of the real-time systems into a set of components, followed by the decomposition of the real-time systems into a set of aspects.
- RTCOM, a real-time component model, has been developed within ACCORD. RTCOM consists of three parts, namely: functional part, run-time part and the composition part. Our focus so far has been on functional and run-time part of the RTCOM. RTCOM is a unique component model for real-time systems as it supports weaving of aspects into the functional code of the component, while preserving the information hiding through the notion of mechanisms (fixed parts of components) and operations (parts of the component that can be modified by aspect weaving). We have developed a description language for maintaining the WCET information of aspects and components within the run-time part of the RTCOM.
- A method for analyzing the WCET of real-time systems composed using aspects and components, i.e., ACCORD and RTCOM, has been developed. This method we call aspect-level WCET analysis. We have also developed a tool that supports automatic aspect-level

WCET analysis of different configurations of components and aspects. The tool implementation has been done in conjunction with one final year project (described below).

- Several final year projects have been performed within COMET project, e.g.,
  - Structuring aspects in embedded database systems, and
  - Aspect Analyzer: a tool for worst-case execution time analysis of aspects and components.RTCOM

Plans 2003:
Dag Nyström is planned to defend his licentiate thesis May 12. Aleksandra Tesanovic is planned to defend her thesis late May (possibly first week of June), but the exact date is not yet set.

Industrial collaboration
The industrial partners in this project are Volvo Construction Equipments Components AB, Dept. TUE (contact: Nils-Erik Bånkestad) and Upright Database Technology AB (contact: Bengt Gunne). Aleksandra and Dag have done an industrial stay at Volvo for two complete weeks to gain valuable insight to industrial practice and application needs. This has resulted in a case study report. This year we have had three one-day meetings with our industrial partners. Bengt Gunne has been particularly active in technical discussions about the project and we have discussed future directions. Nils-Erik has provided us with valuable input regarding application requirements and implementation requirements. Another case study report is intended to be done, initiated by Dag Nyström.

Publications

[1] Aleksandra Tesanovic, Dag Nyström, Jörgen Hansson, and Christer Norström, ”Embedded Databases for Embedded Real-Time Systems: Component-based Approach”, Technical report, (85 pages) 2001.
[2] Aleksandra Tesanovic, Dag Nyström, Jörgen Hansson, and Christer Norström, ”COMET: a COMponent-based Embedded real-Time database”, Technical Report (submitted for publication), 2001.
[3] Aleksandra Tesanovic, Dag Nyström, Jörgen Hansson, and Christer Norström, “Software Developmnet Tools for Embedded Databases in Embedded Real-Time systems”, Poster presentation at RTiS, 2001.
[4] D. Nyström, A. Tesanovic, C. Norström, J. Hansson, and N.-E. Bånkestad, Data Management Issues in Vehicle Control Systems: A Case Study, in Proceedings of the 14th Euromicro Conference on Real Time Systems, pp. 249--256, IEEE Computer Society, June 2002.
[5] A. Tesanovic, D. Nyström, J. Hansson, and C. Norström, Integrating Symbolic Worst-Case Execution Time Analysis with Aspect-Oriented System Development, in OOPSLA 2002 Workshop on Tools for Aspect-Oriented Software Development, (Seattle, WA), Nov. 2002.
[6] A. Tesanovic, D. Nyström, J. Hansson, and C. Norström, Embedded Databases for Embedded Real-Time Systems: A Component-Based Approach, tech. rep., Department of Computer Science, Linköping University and Department of Computer Engineering, Mälardalen University, Jan. 2002.
[7] A. Tesanovic, D. Nyström, J. Hansson, and C. Norström, Aspect-Level Worst-Case Execution Time Analysis of Real-Time Systems Compositioned Using Aspects and Components, in Proceedings of the 27th IFAC/IFIP/IEEE Workshop on Real-Time Programming (WRTP'03), (Poland), Elsevier, May 2003. To appear.
[8] A. Tesanovic, D. Nyström, J. Hansson, and C. Norström, Towards Aspectual Component-Based Development of Real-Time Systems, in Proceeding of the 9th International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2003), Springer-Verlag, Feb. 2003.
[9] D. Nyström, A. Tesanovic, C. Norström, and J. Hansson, Database Pointers: a Predictable Way of Manipulating Hot Data in Hard Real-Time Systems, in Proceedings of the 9th International Conference on Real-Time and Embedded Computing Systems and Applications (RTCSA 2003), Springer-Verlag, Feb. 2003.

Project homepage: http://www.ida.liu.se/labs/rtslab/projects/ARTES_EmbeddedDatabases/welcome.html