

## Real Time Systems / Embedded Systems

Our research interest is the systematic design and analysis of „computers, that are not perceived as such“ - which is one definition of *embedded systems*. These systems appear in all contexts of daily life, from miniaturized hearing aids to x-ray scanners, cell phones, airbag controllers, anti-lock brakes to fly-by-wire aircraft. Such systems not only have to provide the correct outputs to the environment, they also have to provide these in time. In other words, these are *real-time systems*. Of particular interest for us are the *reactive systems*, which continuously react to (mainly discrete) input events of the environment with corresponding output events.

The number of embedded real-time systems today exceeds by far the number of „classical“ computers. However, this area is still a comparatively new field within computer science. In the past, application experts without a specific computer science background have primarily developed such systems. However, because of the ever-increasing complexity of today's applications, this becomes less and less practical.

### Results

Current research activities concentrate on the development of reactive embedded real-time systems. Key areas are

- The model-based design of complex reactive systems,
- Reactive processors, and
- Deterministic concurrency and synchronous languages.

The activities on the **model-based design of complex reactive systems** concentrate on the *modelling pragmatics*, that is, the practical aspects of creating, maintaining and visualizing graphical system models. The Kiel Integrated Environment for Layout Eclipse Rich Client (KIELER) is a prototypical-modelling environment that serves as a test bed to explore and validate novel modelling approaches. A key enabler is the ability to automatically compute the layout of graphical models. This frees the user from the tedious task of manually drawing diagrams, and allows novel techniques such as customized views during simulation. In 2009, KIELER was developed to the point that it largely replaced its predecessor KIEL, and included novel capabilities such as the automatic layout of data-flow diagrams and an interface to UC Berkeley's Ptolemy system as a simulation backbone.

**Reactive Processors** aim to implement reactive behaviour with deterministic behaviour and minimal resource usage. The Kiel Esterel Processor (KEP) is a reactive processor that supports concurrency through multithreading and offers highly predictable timing at minimal power consumption. In 2009, developments focused on the Kiel Lustre Processor, a reactive processor for the synchronous data-flow language Lustre.

The major result in the area **deterministic concurrency and synchronous languages** is the development of *Synchronous C (SC)* and *Synchronous Java (SJ)*, which are lightweight mechanisms to embed deterministic concurrency in C and Java. SC and SJ are inspired by the reactive processing paradigm, but are implemented as macros/classes expressed in standard C/Java, available as open-source code. Hence SC and SJ require neither special hardware nor a special compiler. However, SC is able to take advantage of machine instructions (through gcc embeddings) that are not directly accessible in C.

### Personnel

Head of the group: Prof. Dr. R. von Hanxleden; Secretary: S. Lersmacher (50%), G. Walsdorf (50%)  
Technical Staff: T. Grebien (50%)

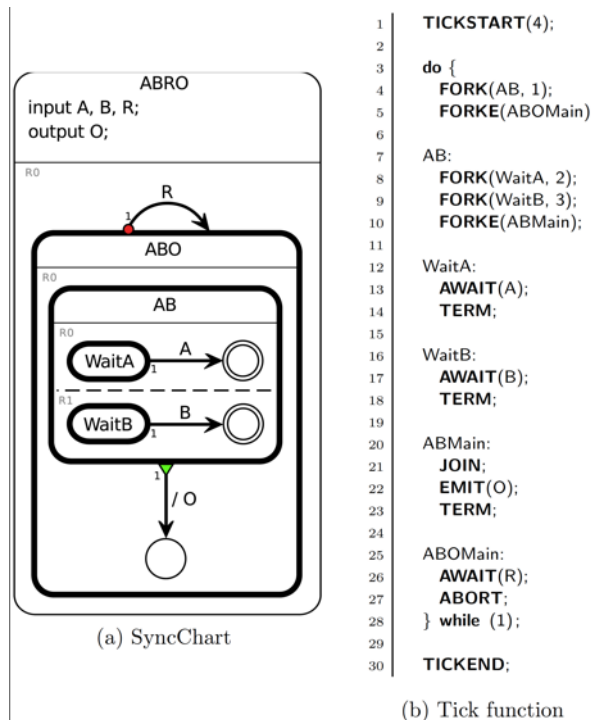


Fig. 1: Example of SyncChart and corresponding tick function for Synchronous C program.

Scientific Staff:

Dipl.-Inf. H. Fuhrmann	01.01.-31.12.2009	Landesmittel
Dipl.-Inf. M. Spönemann	01.04.-31.12.2009	Landesmittel
Dipl.-Inf. C. Traulsen	01.01.-31.12.2009	Landesmittel

▶ Lectures, Seminars, and Laboratory Course Offers

Winter 2008/2009

MS1103: Entwurf eingebetteter Echtzeitsysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,  
R. von Hanxleden (+ H. Fuhrmann)

A5.3.3: Fortgeschrittenenpraktikum - Synchrone Sprachen, 4 hrs Exercise/Week,  
R. von Hanxleden (+ C. Traulsen)

BA6.1: Projektmodul - Echtzeitsysteme/Eingebettete Systeme (Synchrone Sprachen), 6 hrs Exercise/Week,  
R. von Hanxleden (+ C. Traulsen)

MSS1101: Seminar -Echtzeitsysteme/Eingebettete Systeme (Eclipse Technologien), 2 hrs Seminar/Week,  
R. von Hanxleden (+ H. Fuhrmann)

Oberseminar Echtzeitsysteme/Eingebettete Systeme, 2 hrs Seminar/Week,  
R. von Hanxleden

Summer 2009

A5.3.3: Fortgeschrittenenpraktikum - Echtzeitsysteme/Eingebettete Systeme, 4 hrs Exercise/Week,



Fig. 2: Excursion to Daimler Center for Automotive IT Innovations, Berlin (09.10.).

R. von Hanxleden (+ H. Fuhrmann, M. Spönemann)

BA6.1: Projektmodul - Echtzeitsysteme/Eingebettete Systeme, 6 hrs Exercise/Week,

R. von Hanxleden (+ H. Fuhrmann)

G2.1: Informatik II - Algorithmen und Datenstrukturen, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. von Hanxleden (+ H. Schnoor)

MS1101: Modellbasierter Entwurf und Verteilte Echtzeitsysteme, 4 (+ 2) hrs Lecture (+ Exercises)/Week,

R. von Hanxleden (+ H. Fuhrmann)

MSS1101: Seminar - Echtzeitsysteme/Eingebettete Systeme (Seminar Synthese Graphischer Systemmodelle), 2 hrs Seminar/Week,

R. von Hanxleden (+ M. Spönemann)

Oberseminar Echtzeitsysteme/Eingebettete Systeme, 2 hrs Seminar/Week,

R. von Hanxleden

*Winter 2009/2010*

A5.3.3: Fortgeschrittenenpraktikum - Echtzeitsysteme/Eingebettete Systeme (Modellierung in Eclipse), 4 hrs Exercise/Week,

R. von Hanxleden (+ M. Spönemann, H. Fuhrmann)

BA6.1: Projektmodul - Echtzeitsysteme/Eingebettete Systeme (Modellierung in Eclipse), 6 hrs Exercise/Week,

R. von Hanxleden (+ M. Spönemann, H. Fuhrmann)

MS1102: Synchrone Sprachen, 4 (+ 2) hrs Exercise (+ Exercises)/Week,

R. von Hanxleden (+ C. Traulsen)

MSS1101: Seminar -Echtzeitsysteme/Eingebettete Systeme (Modellierung und Ausführung Nebenläufiger Systeme), 2 hrs Seminar/Week,

R. von Hanxleden (+ H. Fuhrmann, M. Spönemann, C. Traulsen)

Oberseminar Echtzeitsysteme/Eingebettete Systeme, 2 hrs Seminar/Week,

R. von Hanxleden

## Third-Party Funds

KoSSE, *Modellbasierte Entwurfsmethoden für eine neue Generation elektronischer Stellwerke (MENGES)*,

01.08.2009-31.07.2012 (171.584 Euro)

Alexander von Humboldt-Stiftung, *Forschungsstipendium für erfahrene Wissenschaftler*, 01.01.-01.06.2009 (14.700 Euro)

## Further Cooperation, Consulting, and Technology Transfer

Cooperation with Edward A. Lee, University of California, Berkeley, on the automatic layout of Ptolemy II diagrams and simulation of SyncCharts.

Cooperation with Michael Mendler, Bamberg University, on worst-case reaction time analysis.

Cooperation with Petra Mutzel, University of Dortmund, on layout algorithms with port constraints.

Cooperation with Partha Roop and Sidharta Andalām, University of Auckland, New Zealand, on reactive processors. Partha Roop visited our group on a Humboldt Fellowship 01.01. – 30.06.09.

Cooperation with the Software Engineering group (Prof. Hasselbring), b+m Informatik AG and Funkwerk Information Technologies GmbH on the model-based design of railway signalling applications (project MENGES).

Cooperation with CEA List (Saclay, Paris), on pragmatics of UML2 modeling.

Cooperation with the Daimler Center for Automotive IT Innovations (Berlin), on the automatic layout of Simulink diagrams.

Cooperation with ETAS/Bosch, on visual model exploration.

## Diploma, Bachelor and Master Theses

F. Starke, *Executing Safe State Machines with the Kiel Esterel Processor*, 09.01.2009

M. Spönemann, *On the Automatic Layout of Data Flow Diagrams*, 19.03.2009

M. Schmeling, *ThinKCharts - The Thin KIELER SyncCharts Editor*, 02.09.2009

N. Beckel, *View Management for Visual Modeling*, 16.10.2009

Ö. Bayramoglu, *KIELER Infrastructure for Textual Modeling*, 03.12.2009

C. Motika, *Semantics and Execution of Domain Specific Models - KlePto and an Execution Framework*, 19.12.2009

## Publications

Published in 2009

S. Andalām, P. Roop, A. Girault, C. Traulsen, *PRET-C: A new language for programming precision timed architectures*, 6922, INRIA Grenoble Rhone-Alpes, (2009)

S. Andalām, P. Roop, A. Girault, C. Traulsen, *PRET-C: A new language for programming precision timed architectures*, Proceedings of the Workshop on Reconciling Performance with Predictability (RePP), Embedded Systems Week, October 2009, (2009)

H. Fuhrmann, R. von Hanxleden, *Enhancing Graphical Model-Based System Design - An Avionics Case Study*, Technical Report 0901, Christian-Albrechts-Universität Kiel, Department of Computer Science, January 2009, (2009)

- H. Fuhrmann, R. von Hanxleden, *On the Pragmatics of Model-Based Design*, Technical Report 0913, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, May 2009, (2009)
- H. Fuhrmann, R. von Hanxleden, *Enhancing Graphical Model-Based System Design - An Avionics Case Study*, Conjoint workshop of the European Research Consortium for Informatics and Mathematics (ERCIM) and Dependable Embedded Components and Systems (DECOS) at SAFECOMP'09, Hamburg, Germany, September 2009, (2009)
- H. Fuhrmann, M. Spönemann, C. Motika, M. Matzen, S. Knauer, R. von Hanxleden, *Enhancing Graphical Modeling in Eclipse with KIELER*, Poster at Eclipse Summit Europe 2009, Ludwigsburg, Germany, October 2009, (2009)
- H. Fuhrmann, R. von Hanxleden, *Exploring Modeling Pragmatics with Ptolemy and KIELER*, Presentation at the Eighth Biennial Ptolemy Miniconference, Berkeley, CA, USA, 16 October 2009, (2009)
- R. von Hanxleden, *SyncCharts in C-A Proposal for Light-Weight, Deterministic Concurrency*, SYNCHRON'09 - Proceedings of Dagstuhl Seminar 09481, Internationales Begegnungs- und Forschungszentrum IBFI, Schloss Dagstuhl, Germany, (2009)
- A. Benveniste, S. A. Edwards, E. Lee, K. Schneider, R. von Hanxleden, *SYNCHRON'09 - Proceedings of Dagstuhl Seminar 09481*, Internationales Begegnungs- und Forschungszentrum IBFI, Schloss Dagstuhl, Germany, (2009)
- R. von Hanxleden, *SyncCharts in C. Technical Report 0910*, Christian-Albrechts-Universität Kiel, Department of Computer Science, May 2009, (2009)
- R. von Hanxleden, *SyncCharts in C-A Proposal for Light-Weight, Deterministic Concurrency*, Proceedings of the International Conference on Embedded Software (EMSOFT'09), Grenoble, France, October 2009, (2009)
- M. Mendler, R. von Hanxleden, C. Traulsen, *WCRT Algebra and Interfaces for Esterel-Style Synchronous Processing*, Proceedings of the Design, Automation and Test in Europe (DATE'09), Nice, France, April 2009, (2009)
- C. Motika, H. Fuhrmann, R. von Hanxleden, *Semantics and Execution of Domain Specific Models.*, Technical Report 0923, Christian-Albrechts-Universität Kiel, Department of Computer Science, December 2009, (2009)
- P. Roop, S. Andalam, R. von Hanxleden, S. Yuan, C. Traulsen, *Tight WCRT Analysis for Synchronous C Programs*, Technical Report 0912, Christian-Albrechts-Universität Kiel, Department of Computer Science, Kiel, Germany, May 2009, (2009)
- P. Roop, S. Andalam, R. von Hanxleden, S. Yuan, C. Traulsen, *Tight WCRT Analysis for Synchronous C Programs*, Proceedings of the International Conference on Compilers, Architecture, and Synthesis for Embedded Systems (CASES'09), Grenoble, France, October 2009, (2009)
- A. Schipper, H. Fuhrmann, R. von Hanxleden, *Visual Comparison of Graphical Models*, Proceedings of the Fourth IEEE International Workshop UML and AADL, held in conjunction with the 14th International International Conference on Engineering of Complex Computer Systems (ICECCS'09), Potsdam, Germany, 2 June 2009, (2009)
- M. Spönemann, H. Fuhrmann, R. von Hanxleden, *Automatic Layout of Data Flow Diagrams in KIELER and Ptolemy II*, Technical Report 0914, Christian-Albrechts-Universität zu Kiel, Department of Computer Science, July 2009, (2009)
- F. Starke, C. Traulsen, R. von Hanxleden, *Executing Safe State Machines on a Reactive Processor*, Technical Report 0907, Christian-Albrechts-Universität Kiel, Department of Computer Science, Kiel, Germany, March 2009, (2009)
- H. Fuhrmann, R. von Hanxleden, *On the Pragmatics of Model-Based Design*, Proceedings of the 15th International Monterey Workshop on Foundations of Computer Software, Future Trends and Techniques for Development (2008), LNCS (to appear), Budapest, 2010. Also available as Technical Report 0913, Christian-Albrechts-Universität, (2009)

## Presentations

- C. Traulsen, *Reactive Processors*, Informatik-Symposium Schleswig-Holstein, Neumünster, 23.03.2009
- M. Mendler, R. von Hanxleden, C. Traulsen, *WCRT Algebra and Interfaces for Esterel-Style Synchronous Processing*, In Proceedings of the Design, Automation and Test in Europe (DATE'09, Nice, France, 21.-24.04.2009
- A. Schipper, H. Fuhrmann, R. von Hanxleden, *Visual Comparison of Graphical Models*, In Proceedings of the Fourth IEEE International Workshop UML and AADL, held in conjunction with the 14th International International Conference on Engineering of Complex Computer Systems (ICECCS'09), Potsdam, Germany, 02.06.2009

- C. Traulsen, *Synchronous Languages and Reactive Processing*, Colloquium of the School of Physics, State University Irkutsk, Irkutsk, Russia, 10.09.2010
- H. Fuhrmann, R. von Hanxleden, *Enhancing Graphical Model-Based System Design— An Avionics Case Study*, In Conjoint workshop of the European Research Consortium for Informatics and Mathematics (ERCIM) and Dependable Embedded Components and Systems (DECOS) at SAFECOMP'09, Hamburg, Germany, 15.09.2009
- M. Spönemann, H. Fuhrmann, R. von Hanxleden, P. Mutzel, *Port Constraints in Hierarchical Layout of Data Flow Diagrams*, In Proceedings of the 17th International Symposium on Graph Drawing (GD'09), 22.-25.09.2009
- R. von Hanxleden, *SyncCharts in C*, Excursion Daimler Center for Automotive IT Innovations, Berlin, 08.10.2010
- H. Fuhrmann, *Enhancing Graphical Model-Based System Design - KIELER*, Excursion Daimler Center for Automotive IT Innovations, Berlin, 08.10.2010
- P. Roop, S. Andalām, R. von Hanxleden, S. Yuan, *Tight WCRT Analysis for Synchronous C Programs*, In Proceedings of the International Conference on Compilers, Architecture, and Synthesis for Embedded Systems (CASES'09), Grenoble, France, 11.-18.10.2009
- R. von Hanxleden, *SyncCharts in C— A Proposal for Light-Weight, Deterministic Concurrency*, In Proceedings of the International Conference on Embedded Software (EMSOFT'09, Grenoble, France, 11.-18.10.2009
- S. Andalām, P. Roop, A. Girault, C. Traulsen, *PRET-C: A new language for programming precision timed architectures*, In Proceedings of the Workshop on Reconciling Performance with Predictability (RePP) Embedded Systems Week, Grenoble, Frankreich, 13.10.2009
- H. Fuhrmann, R. von Hanxleden, *Exploring Modeling Pragmatics with Ptolemy and KIELER.*, Presentation at the Eighth Biennial Ptolemy Miniconference, Berkeley, USA, 16.10.2009
- H. Fuhrmann, M. Spönemann, C. Motika, M. Matzen, R. von Hanxleden, *Enhancing Graphical Modeling in Eclipse with KIELER*, Poster at Eclipse Summit Europe 2009, Ludwigsburg, Germany, 27.-29.10.2009

## Further Activities and Events

Excursion to REXSON GmbH, Kiel (25.02.).

Excursion to Daimler Center for Automotive IT Innovations, Berlin (09.10.).

### **R. von Hanxleden:**

Member of the *IEEE Esterel v7 Standardization Working Group*.

Member of the *ArtistDesign European Network of Excellence on Embedded System Design*.

### **C. Motika, C. Schneider:**

Demonstration of the Model-Railway, Girls' Day 2009 (23.04.)

### **R. von Hanxleden, C. Traulsen:**

Reviewer for *Transactions on Embedded Computing Systems* and the *EURASIP Journal on Embedded Systems*.