

# Lecture Notes in Computer Science

Edited by G. Goos, J. Hartmanis, and J. van Leeuwen

2491

**Springer**

*Berlin*

*Heidelberg*

*New York*

*Barcelona*

*Hong Kong*

*London*

*Milan*

*Paris*

*Tokyo*

Alberto Sangiovanni-Vincentelli  
Joseph Sifakis (Eds.)

# Embedded Software

Second International Conference, EMSOFT 2002  
Grenoble, France, October 7-9, 2002  
Proceedings



Springer

Series Editors

Gerhard Goos, Karlsruhe University, Germany  
Juris Hartmanis, Cornell University, NY, USA  
Jan van Leeuwen, Utrecht University, The Netherlands

Volume Editors

Alberto Sangiovanni-Vincentelli  
University of California at Berkeley, Department of EECS  
Berkeley, CA 94720, USA  
E-mail: alberto@eecs.berkeley.edu

Joseph Sifakis  
Verimag, Centre Equation  
2 rue de Vignate, 38610 Gieres, France  
E-mail: Joseph.Sifakis@imag.fr

Cataloging-in-Publication Data applied for

Die Deutsche Bibliothek - CIP-Einheitsaufnahme

Embedded software : second international conference ; proceedings / EMSOFT 2002, Grenoble, France, October 7 - 9, 2002. Alberto Sangiovanni-Vincentelli ; Joseph Sifakis (ed.). - Berlin ; Heidelberg ; New York ; Hong Kong ; London ; Milan ; Paris ; Tokyo : Springer, 2002  
(Lecture notes in computer science ; Vol. 2491)  
ISBN 3-540-44307-X

CR Subject Classification (1998): C.3, D.1-4, F.3

ISSN 0302-9743

ISBN 3-540-44307-X Springer-Verlag Berlin Heidelberg New York

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, re-use of illustrations, recitation, broadcasting, reproduction on microfilms or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer-Verlag. Violations are liable for prosecution under the German Copyright Law.

Springer-Verlag Berlin Heidelberg New York  
a member of BertelsmannSpringer Science+Business Media GmbH

<http://www.springer.de>

© Springer-Verlag Berlin Heidelberg 2002  
Printed in Germany

Typesetting: Camera-ready by author, data conversion by Olgun Computergrafik  
Printed on acid-free paper      SPIN 10870669      06/3142      5 4 3 2 1 0

# Preface

The purpose of the EMSOFT Workshop, inaugurated last year at Lake Tahoe, is to bring together researchers and practitioners interested in the foundations and methods of embedded software design with the goal of improving substantially the state of the art and stimulating the debate between researchers and designers. The scope of the EMSOFT Workshop spans all aspects of embedded software, including operating systems and middleware, programming languages and compilers, modeling and validation, software engineering and programming methodologies, scheduling and execution-time analysis, formal methods, communication protocols and fault tolerance.

While the first Workshop included only invited papers because of the need to establish a common framework and a basis for the scientific contributions, for this second EMSOFT, we attempted to strike a balance between invited and selected contributions. The program included 17 selected and 13 invited contributions. The invited speakers were: Giorgio Buttazzo (University of Pavia), Paolo Faraboschi (Hewlett-Packard Laboratories), Nicolas Halbwachs (Verimag), David Harel (Weizmann Institute), Christoph Kirsch (University of California at Berkeley), Luciano Lavagno (Politecnico di Torino and Cadence Research Labs), Nancy Leveson (MIT), Sharad Malik (Princeton), Al Mok (University of Texas at Austin), Amir Pnueli (Weizmann Institute), Lui Sha (University of Illinois at Urbana-Champaign), Douglas Schmidt (University of California at Irvine), and Bran Selic (Rational).

The program covers a wide variety of topics including requirements description and modeling, validation and analysis, synchronous languages, scheduling, real-time architectures and middleware, compilation and implementation, computerized control, and dependability. EMSOFT was colocated with CASES 2002 (International Conference on Compilers, Architectures and Synthesis for Embedded Systems), and to enhance interaction between the respective communities CASES and EMSOFT organized two joint invited sessions. The CASES invited speakers at the joint sessions were: John Rayfield (ARM Ltd.), Giovanni De Micheli (Stanford University), and Jens Palsberg (Purdue University).

The members of the EMSOFT Steering Committee were: Gerard Berry (Esterel Technologies), Tom Henzinger (Stanford University), Hermann Kopetz (TU Vienna), Edward Lee (UC Berkeley), Ragunathan Rajkumar (Carnegie Mellon University), Alberto Sangiovanni-Vincentelli (UC Berkeley), Douglas Schmidt (Washington University), Joseph Sifakis (Verimag), and John Stankovic (University of Virginia).

The EMSOFT 2002 Program Committee this year was: Rajeev Alur (University of Pennsylvania), Gerard Berry (Esterel Technologies), Manfred Broy (Technical University of Munich), Tom Henzinger (University of California at Berkeley),

Kevin Jeffay (University of North Carolina), Hermann Kopetz (Technical University of Vienna), Edward Lee (University of California at Berkeley), Sang Lyul Min (Seoul National University), Martin Rinard (MIT), John Rushby (SRI), Alberto Sangiovanni-Vincentelli (University of California at Berkeley), Shankar Sastry (University of California at Berkeley), Joseph Sifakis (Verimag), John Stankovic (University of Virginia), Lothar Thiele (ETH), Reinhard Wilhelm (Universität des Saarlandes), and Janos Sztipanovits (Vanderbilt University).

We would like to thank the following additional reviewers: Astrit Ademaj, Felice Balarin, Andrea Balluchi, Gunther Bauer, María Victoria Cengarle, Bertrand Delsart, Alberto Ferrari, Romain Guider, Wolfgang Haidinger, Ben Horowitz, Daniel Kaestner, Raimund Kirner, Orna Kupferman, Marc Langenbach, Thomas Losert, Heiko Lötzbeyer, Roman Obermaisser, Paritosh Pandya, Michael Paulitsch, Jan Philipps, Alexander Pretschner, Martin Rappl, Robert Sandner, Marco Sanvido, Joern Schneider, Bernhard Schtz, Katharina Spies, Stephan Thesing, Stavros Tripakis, Sebastian Winkel, and Sergio Yovine.

EMSOFT 2002 was organized by the Verimag laboratory. The Organizing Committee was composed of Joseph Sifakis, Stavros Tripakis, and Sergio Yovine who had the overall responsibility for coordination and helped with the assembly of the final camera-ready copy.

EMSOFT 2002 was held on the premises of the Institut National Polytechnique de Grenoble under the sponsorship of the European Network of Excellence ARTIST, on Advanced Real-Time Systems and received support from the Centre National de la Recherche Scientifique, the Institut National Polytechnique de Grenoble, and Université Joseph Fourier.

July 2002

Alberto Sangiovanni-Vincentelli  
Joseph Sifakis

# Table of Contents

Embedded Systems: Challenges in Specification and Verification . . . . .	1
<i>Amir Pnueli (Invited Speaker)</i>	
An Approach to Designing Safe Embedded Software . . . . .	15
<i>Nancy G. Leveson (Invited Speaker)</i>	
Can Behavioral Requirements Be Executed? (And Why Would We Want to Do So?) . . . . .	30
<i>David Harel (Invited Speaker)</i>	
Platform-Based Embedded Software Design for Multi-vehicle Multi-modal Systems . . . . .	32
<i>T. John Koo, Judith Liebman, Cedric Ma, Benjamin Horowitz, Alberto Sangiovanni-Vincentelli, and Shankar Sastry</i>	
A Giotto-Based Helicopter Control System . . . . .	46
<i>Christoph M. Kirsch, Marco A.A. Sanvido, Thomas A. Henzinger, and Wolfgang Pree</i>	
Principles of Real-Time Programming . . . . .	61
<i>Christoph M. Kirsch (Invited Speaker)</i>	
Time-Safety Checking for Embedded Programs . . . . .	76
<i>Thomas A. Henzinger, Christoph M. Kirsch, Rupak Majumdar, and Slobodan Matic</i>	
Compositional Modeling in Metropolis . . . . .	93
<i>Gregor Gössler and Alberto Sangiovanni-Vincentelli</i>	
Timed Interfaces . . . . .	108
<i>Luca de Alfaro, Thomas A. Henzinger, and Mariëlle Stoelinga</i>	
Description and Schedulability Analysis of the Software Architecture of an Automated Vehicle Control System . . . . .	123
<i>Stavros Tripakis</i>	
Formal Modeling and Analysis of Advanced Scheduling Features in an Avionics RTOS . . . . .	138
<i>Darren Cofer and Murali Rangarajan</i>	
Scalable Applications for Energy-Aware Processors . . . . .	153
<i>Giorgio C. Buttazzo (Invited Speaker)</i>	

Upgrading Embedded Software in the Field: Dependability and Survivability . . . . .	166
<i>Lui Sha (Invited Speaker)</i>	
Real-Time Virtual Resource: A Timely Abstraction for Embedded Systems . . . . .	182
<i>Aloysius K. Mok (Invited Speaker) and Alex Xiang Feng</i>	
JCOD: A Lightweight Modular Compilation Technology for Embedded Java . . . . .	197
<i>Bertrand Delsart, Vania Joloboff, and Eric Paire</i>	
Decreasing Memory Overhead in Hard Real-Time Garbage Collection . . . . .	213
<i>Tobias Ritzau and Peter Fritzson</i>	
Speedup Prediction for Selective Compilation of Embedded Java Programs . . . . .	227
<i>Vincent Colin de Verdière, Sébastien Cros, Christian Fabre, Romain Guider, and Sergio Yovine</i>	
Synchronous Modelling of Asynchronous Systems . . . . .	240
<i>Nicolas Halbwachs (Invited Speaker) and Siwar Baghdadi</i>	
A Protocol for Loosely Time-Triggered Architectures . . . . .	252
<i>Albert Benveniste, Paul Caspi, Paul Le Guernic, Hervé Marchand, Jean-Pierre Talpin, and Stavros Tripakis</i>	
Automatic Production of Globally Asynchronous Locally Synchronous Systems . . . . .	266
<i>Alain Girault and Clément Ménier</i>	
Adaptive and Reflective Middleware for Distributed Real-Time and Embedded Systems . . . . .	282
<i>Douglas C. Schmidt (Invited Speaker)</i>	
Toward an Approximation Theory for Computerised Control . . . . .	294
<i>Paul Caspi and Albert Benveniste</i>	
A New Facility for Dynamic Control of Program Execution: DELI . . . . .	305
<i>Giuseppe Desoli, Nikolay Mateev, Evelyn Duesterwald, Paolo Faraboschi (Invited Speaker), and Josh Fisher</i>	
Design Tools for Application Specific Embedded Processors . . . . .	319
<i>Wei Qin, Subramanian Rajagopalan, Manish Vachharajani, Hangsheng Wang, Xinping Zhu, David August, Kurt Keutzer, Sharad Malik (Invited Speaker), and Li-Shiuan Peh</i>	
Processor Pipelines and Their Properties for Static WCET Analysis . . . . .	334
<i>Jakob Engblom and Bengt Jonsson</i>	



ILP-Based Interprocedural Path Analysis .....	349
<i>Henrik Theiling</i>	
Enhancing Compiler Techniques for Memory Energy Optimizations .....	364
<i>Joseph Zambreno, Mahmut Taylan Kandemir, and Alok Choudhary</i>	
FlexCC2: An Optimizing Retargetable C Compiler for DSP Processors ...	382
<i>Valérie Bertin, Jean-Marc Daveau, Philippe Guillaume,</i>	
<i>Thierry Lepley, Denis Pilat, Claire Richard, Miguel Santana,</i>	
<i>and Thomas Theyry</i>	
Physical Programming: Beyond Mere Logic .....	399
<i>Bran Selic (Invited Speaker)</i>	
Processes, Interfaces and Platforms. Embedded Software Modeling in Metropolis .....	407
<i>F. Balarin, L. Lavagno (Invited Speaker), C. Passerone,</i>	
<i>and Y. Watanabe</i>	
<b>Author Index</b> .....	423