

Editor-in-Chief

*A. Joe Turner, Seneca, SC, USA*

Editorial Board

Foundations of Computer Science

*Mike Hinchey, Lero, Limerick, Ireland*

Software: Theory and Practice

*Michael Goedicke, University of Duisburg-Essen, Germany*

Education

*Arthur Tatnall, Victoria University, Melbourne, Australia*

Information Technology Applications

*Ronald Waxman, EDA Standards Consulting, Beachwood, OH, USA*

Communication Systems

*Guy Leduc, Université de Liège, Belgium*

System Modeling and Optimization

*Jacques Henry, Université de Bordeaux, France*

Information Systems

*Jan Pries-Heje, Roskilde University, Denmark*

ICT and Society

*Jackie Phahlamohlaka, CSIR, Pretoria, South Africa*

Computer Systems Technology

*Paolo Prinetto, Politecnico di Torino, Italy*

Security and Privacy Protection in Information Processing Systems

*Kai Rannenber, Goethe University Frankfurt, Germany*

Artificial Intelligence

*Tharam Dillon, Curtin University, Bentley, Australia*

Human-Computer Interaction

*Annelise Mark Pejtersen, Center of Cognitive Systems Engineering, Denmark*

Entertainment Computing

*Ryohei Nakatsu, National University of Singapore*

## **IFIP – The International Federation for Information Processing**

IFIP was founded in 1960 under the auspices of UNESCO, following the First World Computer Congress held in Paris the previous year. An umbrella organization for societies working in information processing, IFIP's aim is two-fold: to support information processing within its member countries and to encourage technology transfer to developing nations. As its mission statement clearly states,

IFIP's mission is to be the leading, truly international, apolitical organization which encourages and assists in the development, exploitation and application of information technology for the benefit of all people.

IFIP is a non-profitmaking organization, run almost solely by 2500 volunteers. It operates through a number of technical committees, which organize events and publications. IFIP's events range from an international congress to local seminars, but the most important are:

- The IFIP World Computer Congress, held every second year;
- Open conferences;
- Working conferences.

The flagship event is the IFIP World Computer Congress, at which both invited and contributed papers are presented. Contributed papers are rigorously refereed and the rejection rate is high.

As with the Congress, participation in the open conferences is open to all and papers may be invited or submitted. Again, submitted papers are stringently refereed.

The working conferences are structured differently. They are usually run by a working group and attendance is small and by invitation only. Their purpose is to create an atmosphere conducive to innovation and development. Refereeing is also rigorous and papers are subjected to extensive group discussion.

Publications arising from IFIP events vary. The papers presented at the IFIP World Computer Congress and at open conferences are published as conference proceedings, while the results of the working conferences are often published as collections of selected and edited papers.

Any national society whose primary activity is about information processing may apply to become a full member of IFIP, although full membership is restricted to one society per country. Full members are entitled to vote at the annual General Assembly, National societies preferring a less committed involvement may apply for associate or corresponding membership. Associate members enjoy the same benefits as full members, but without voting rights. Corresponding members are not represented in IFIP bodies. Affiliated membership is open to non-national societies, and individual and honorary membership schemes are also offered.

Gunar Schirner   Marcelo Götz  
Achim Rettberg   Mauro C. Zanella  
Franz J. Rammig (Eds.)

# Embedded Systems: Design, Analysis and Verification

4th IFIP TC 10 International  
Embedded Systems Symposium, IESS 2013  
Paderborn, Germany, June 17-19, 2013  
Proceedings

## Volume Editors

Gunar Schirner  
Northeastern University  
Boston, MA, USA  
E-mail: schirner@ece.neu.edu

Marcelo Götz  
Fed. University of Rio Grande do Sul  
Porto Alegre, RS, Brazil  
E-mail: mgoetz@ece.ufrgs.br

Achim Rettberg  
Carl von Ossietzky University  
Oldenburg, Germany  
E-mail: achim.rettberg@iess.org

Mauro C. Zanella  
ZF Friedrichshafen AG  
Friedrichshafen, Germany  
E-mail: mauro.zanella@zf.com

Franz J. Rammig  
Paderborn University  
Paderborn, Germany  
E-mail: franz@upb.de

ISSN 1868-4238

e-ISSN 1868-422X

ISBN 978-3-642-38852-1

e-ISBN 978-3-642-38853-8

DOI 10.1007/978-3-642-38853-8

Springer Heidelberg Dordrecht London New York

Library of Congress Control Number: 2013939604

CR Subject Classification (1998): C.3, C.4, D.2.4, C.2, D.2.11, D.4.7, J.2, J.6, C.0, C.1, B.3, B.8

© IFIP International Federation for Information Processing 2013

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

*Typesetting:* Camera-ready by author, data conversion by Scientific Publishing Services, Chennai, India

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

# Preface

This book presents the technical program of the International Embedded Systems Symposium (IESS) 2013. The design, analysis, and verification of embedded systems are discussed from complementary views in chapters of this book, including design methodologies, dealing with nonfunctional aspects, verification, performance analysis, real-time systems design, and applications examples. The book includes a special chapter dedicated to the BMBF-funded ARAMIS project on Automotive, Railway and Avionics Multicore Systems. In addition, real-world application case studies are presented discussing challenges and realizations of embedded systems.

Over recent years, *embedded systems* have gained an enormous amount of processing power and functionality and have entered several application areas, owing to the fact that many of the formerly external components can now be integrated into a single System-on-Chip. This tendency has resulted in a dramatic reduction in the size and cost of embedded systems. As a unique technology, the design of embedded systems is an essential element of many innovations.

Embedded systems meet their performance goals, including real-time constraints, through a combination of special-purpose hardware and software components tailored to the system requirements. Both the development of new features and the reuse of existing intellectual property components are essential to keeping up with ever-demanding customer requirements. Furthermore, design complexities are steadily growing with an increasing number of components that have to cooperate properly. Embedded system designers have to cope with multiple goals and constraints simultaneously, including timing, power, reliability, dependability, maintenance, packaging and, last but not least, price.

The significance of these constraints varies depending on the application area a system is targeted for. Typical embedded applications include consumer electronic, automotive, medical, and communication devices.

The *International Embedded Systems Symposium (IESS)* is a unique forum to present novel ideas, exchange timely research results, and discuss the state of the art and future trends in the field of embedded systems. Contributors and participants from both industry and academia take active part in this symposium. The IESS conference is organized by the Computer Systems Technology committee (TC10) of the International Federation for Information Processing (IFIP), especially the working group 3.2 “Embedded Systems.”

IESS is a true interdisciplinary conference on the design of embedded systems. Computer Science and Electrical Engineering are the predominant academic disciplines concerned with the topics covered in IESS, but many applications also involve civil, mechanical, aerospace, and automotive engineering, as well as various medical disciplines.

In 2005, IESS was held for the first time in Manaus, Brazil. In this initial instalment, IESS 2005 was very successful with 30 accepted papers ranging from specification to embedded systems application. IESS 2007 was the second edition of the symposium held in Irvine (CA), USA, with 35 accepted papers and two tutorials ranging from analysis, design methodologies to case studies from automotive and medical applications. IESS 2009 took place at the wonderful Schloss Montfort in Langenargen, Germany, with 28 accepted papers and two tutorials ranging from efficient modeling toward challenges for designers of fault-tolerant embedded systems.

*IESS 2013* was held in Paderborn, Germany, at the Heinz Nixdorf Museums-Forum (HNF), which hosts the world largest computer museum.

The articles presented in this book are the result of a thorough review process implemented by the Technical Program Committee. Out of 42 valid submissions, 22 full papers were accepted yielding an acceptance rate of 52%. In addition, eight short papers are included yielding an overall acceptance rate of 74%.

First and foremost, we thank our sponsors dSPACE, ZF Friedrichshafen AG, the Carl von Ossietzky University Oldenburg, and the Paderborn University for their generous financial support of this conference. Without these contributions, IESS 2013 would not have been possible in its current form. Very special thanks to the Heinz Nixdorf Museums-Forum (HNF) for hosting the event. Especially, we thank Gabriele Himmelsbach from HNF for her outstanding organizational support in arranging the facilities and venue.

We would also like to thank IFIP as the organizational body for the promotion and support of the IESS conference.

Last but not least, we thank the authors for their interesting research contributions and the members of the Technical Program Committee for their valuable time and effort in reviewing the articles.

June 2013

Gunar Schirner  
Marcelo Götz  
Achim Rettberg  
Mauro C. Zanella  
Franz J. Rammig

**IFIP TC10 Working Conference:  
International Embedded Systems Symposium  
(IESS) June 17–19, 2013  
Heinz Nixdorf Muesums-Forum, Paderborn,  
Germany**

**General Chairs**

Achim Rettberg

Carl v. Ossietzky University, Oldenburg,  
Germany

Mauro C. Zanella

ZF Friedrichshafen AG, Friedrichshafen,  
Germany

**General Co-chair**

Franz J. Rammig

University of Paderborn, Germany

**Program Co-chair**

Marcelo Götz

Federal University of Rio Grande do Sul, Brazil

Gunar Schirner

Northeastern University Boston, USA

**Local Arrangements Chair**

Achim Rettberg

Carl von Ossietzky University, Oldenburg,  
Germany

**Publicity Chair**

Marco Wehrmeister

Santa Catarina State University, Brazil

**Web Chair**

Tayfun Gezgin OFFIS

Institute for Information Technology,  
Oldenburg, Germany

## Finance Chair

Achim Rettberg

Carl von Ossietzky University, Oldenburg,  
Germany

## Technical Program Committee

Samar Abdi

Concordia University Montreal, Canada

Christian Allmann

Audi Electronics Venture, Germany

Michael Amann

ZF Friedrichshafen, Germany

Richard Anthony

The University of Greenwich, UK

Jürgen Becker

University of Karlsruhe, Germany

Alecio Binotto

UFRGS, Brazil and LBNL, USA

Christophe Bobda

University of Potsdam, Germany

Luigi Carro

UFRGS, Brazil

Florian Dittmann

TWT, Germany

Rainer Doemer

University of California at Irvine, USA

Cecilia Ekelin

Volvo Technology Corporation, Sweden

Rolf Ernst

Technical University Braunschweig, Germany

Danubia B. Espindola

FURG, Brazil

Masahiro Fujita

University of Tokyo, Japan

Andreas Gerstlauer

University of Texas Austin, USA

Marcelo Götz

UFRGS, Brazil

Kim Grüttner

OFFIS, Germany

Andreas Hein

Carl von Ossietzky University, Oldenburg,  
Germany

Joerg Henkel

University of Karlsruhe, Germany

Stefan Henkler

OFFIS, Germany

Carsten Homburg

dSPACE, Germany

Uwe Honekamp

Vector Informatik, Germany

Michael Huebner

Ruhr University Bochum, Germany

Marcel Jackowski

USP, Brazil

Ricardo Jacobi

University of Brasilia, Brazil

Michael Keckeisen

ZF Friedrichshafen, Germany

Timo Kerstan

dSPACE, Germany

Amin Khajeh

Intel, USA

Doo-Hyun Kim

Konkuk University, Korea

Bernd Kleinjohann

C-LAB, Germany

Hermann Kopetz

Technical University Vienna, Austria

Marcio Kreutz

UFRN, Brazil

Horst Krimmel

ZF Friedrichshafen, Germany

Thomas Lehmann

HAW Hamburg, Germany

Armin Lichtblau

Mentor Graphics, Germany

Patrick Lysaght

Xilinx Research Labs, USA

Roger May

Altera, UK



Adam Morawiec	ECSI, France
Wolfgang Nebel	Carl von Ossietzky University, Oldenburg, Germany
Mike Olivarez	Freescale Semiconductor, USA
Carlos Pereira	UFRGS, Brazil
Edison Pignaton de Freitas	IME, Brazil
Franz Rammig	University of Paderborn, Germany
Achim Rettberg	Carl von Ossietzky University, Oldenburg, Germany
Carsten Rust	Sagem Orga, Germany
Stefan Schimpf	ETAS, Germany
Juergen Schirmer	Robert Bosch GmbH, Stuttgart, Germany
Gunar Schirner	Northeastern University Boston, USA
Aviral Shrivastava	Arizona State University, USA
Joachim Stroop	dSPACE, Germany
Hiroyuki Tomiyama	Ritsumeikan University, Japan
Flavio R. Wagner	UFRGS, Brazil
Marco Wehrmeister	UDESC, Brazil
Marilyn Wolf	Georgia Institute of Technology, USA
Mauro Zanella	ZF Friedrichshafen, Germany
Jianwen Zhu	University of Toronto, Canada

## Co-organizing Institution

IFIP TC 10, WG 10.2 and WG 10.5

## Sponsors

dSPACE GmbH  
ZF Lemförder GmbH  
Carl von Ossietzky University, Oldenburg  
University of Paderborn

# Table of Contents

## Design Methodologies

TECSCE: HW/SW Codesign Framework for Data Parallelism Based on Software Component . . . . .	1
<i>Takuya Azumi, Yasaman Samei Syahkal, Yuko Hara-Azumi, Hiroshi Oyama, and Rainer Dömer</i>	
Programming Robots with Events . . . . .	14
<i>Truong-Giang Le, Dmitriy Fedosov, Olivier Hermant, Matthieu Manceny, Renaud Pawlak, and Renaud Rioboo</i>	
Joint Algorithm Developing and System-Level Design: Case Study on Video Encoding . . . . .	26
<i>Jiaxing Zhang and Gunar Schirner</i>	
Automatic Execution of Test Cases on UML Models of Embedded Systems . . . . .	39
<i>Marco A. Wehrmeister and Gian R. Berkenbrock</i>	

## Non-functional Aspects of Embedded Systems

Compiler Optimizations Do Impact the Reliability of Control-Flow Radiation Hardened Embedded Software . . . . .	49
<i>Rafael B. Parizi, Ronaldo R. Ferreira, Luigi Carro, and Álvaro F. Moreira</i>	
Power Reduction in Embedded Systems Using a Design Methodology Based on Synchronous Finite State Machines . . . . .	61
<i>Douglas P.B. Renaux and Fabiana Pöttker</i>	
Low-Power Processors Require Effective Memory Partitioning . . . . .	73
<i>Leonardo Steinfeld, Marcus Ritt, Fernando Silveira, and Luigi Carro</i>	
Enhancement of System-Lifetime by Alternating Module Activation . . . .	82
<i>Frank Sill Torres</i>	

## Verification

Model Checking Memory-Related Properties of Hardware/Software Co-designs . . . . .	92
<i>Marcel Pockrandt, Paula Herber, Verena Klös, and Sabine Glesner</i>	

Reducing Re-verification Effort by Requirement-Based Change Management ..... 104  
*Markus Oertel and Achim Rettberg*

Formal Deadlock Analysis of SpecC Models Using Satisfiability Modulo Theories ..... 116  
*Che-Wei Chang and Rainer Dömer*

Automated Functional Verification of Application Specific Instruction-set Processors ..... 128  
*Marcela Šimková, Zdeněk Přikryl, Zdeněk Kotásek, and Tomáš Hruška*

**Performance Analysis**

Compressing Microcontroller Execution Traces to Assist System Analysis ..... 139  
*Azzeddine Amiar, Mickaël Delahaye, Yliès Falcone, and Lydie du Bousquet*

Hardware and Software Implementations of Prim’s Algorithm for Efficient Minimum Spanning Tree Computation ..... 151  
*Artur Mariano, Dongwook Lee, Andreas Gerstlauer, and Derek Chiou*

A Passive Monitoring Tool for Evaluation of Routing in WirelessHART Networks ..... 159  
*Gustavo Kunzel, Jean Michel Winter, Ivan Muller, Carlos Eduardo Pereira, and João Cesar Netto*

Automated Identification of Performance Bottleneck on Embedded Systems for Design Space Exploration ..... 171  
*Yuki Ando, Seiya Shibata, Shinya Honda, Hiroyuki Tomiyama, and Hiroaki Takada*

**ARAMIS Special Session**

Compositional Timing Analysis of Real-Time Systems Based on Resource Segregation Abstraction ..... 181  
*Philipp Reinkemeier and Ingo Stierand*

Towards Virtualization Concepts for Novel Automotive HMI Systems... 193  
*Simon Gansel, Stephan Schnitzer, Frank Dürr, Kurt Rothermel, and Christian Maihöfer*

Exploiting Segregation in Bus-Based MPSoCs to Improve Scalability of Model-Checking-Based Performance Analysis for SDFAs ..... 205  
*Maher Fakih, Kim Grüttner, Martin Fränze, and Achim Rettberg*

Formal Verification of Concurrent Embedded Software . . . . .	218
<i>Dirk Nowotka and Johannes Traub</i>	

On the Homogeneous Multiprocessor Virtual Machine Partitioning Problem . . . . .	228
<i>Stefan Groesbrink</i>	

## Real-Time Systems

Fault-Tolerant Deployment of Real-Time Software in AUTOSAR ECU Networks . . . . .	238
<i>Kay Klobedanz, Jan Jatzkowski, Achim Rettberg, and Wolfgang Mueller</i>	

Adaptive Total Bandwidth Server: Using Predictive Execution Time . . . .	250
<i>Kiyofumi Tanaka</i>	

Real-Time Service-Oriented Architectures: A Data-Centric Implementation for Distributed and Heterogeneous Robotic System . . . .	262
<i>Pekka Alho and Jouni Mattila</i>	

Contract-Based Compositional Scheduling Analysis for Evolving Systems . . . . .	272
<i>Tayfun Gezgin, Stefan Henkler, Achim Rettberg, and Ingo Stierand</i>	

## Embedded System Applications

Extending an IEEE 42010-Compliant Viewpoint-Based Engineering-Framework for Embedded Systems to Support Variant Management . . . . .	283
<i>André Heuer, Tobias Kaufmann, and Thorsten Weyer</i>	

Proteus Hypervisor: Full Virtualization and Paravirtualization for Multi-core Embedded Systems . . . . .	293
<i>Katharina Gilles, Stefan Groesbrink, Daniel Baldin, and Timo Kerstan</i>	

A Structural Parametric Binaural 3D Sound Implementation Using Open Hardware . . . . .	306
<i>Bruno Dal Bó Silva and Marcelo Götz</i>	

## Real-Time Aspects in Distributed Systems

Modeling Time-Triggered Ethernet in SystemC/TLM for Virtual Prototyping of Cyber-Physical Systems . . . . .	318
<i>Zhenkai Zhang and Xenofon Koutsoukos</i>	

I/O Sharing in a Multi-core Kernel for Mixed-Criticality Applications.....	331
<i>Gang Li and Søren Top</i>	
Evaluating the Impact of Integrating a Security Module on the Real-Time Properties of a System.....	343
<i>Sunil Malipatlolla and Ingo Stierand</i>	
<b>Author Index</b> .....	<b>353</b>