



Dependable Computing and Fault-Tolerant Systems

Edited by

A. Avižienis, H. Kopetz, J. C. Laprie

Advisory Board

*J. A. Abraham, V. K. Agarwal, T. Anderson, W. C. Carter,
A. Costes, F. Cristian, M. Dal Cin, K. E. Forward, G. C. Gilley,
J. Goldberg, A. Goyal, H. Ihara, R. K. Iyer, J. P. Kelly,
G. Le Lann, B. Littlewood, J. F. Meyer, B. Randell,
A. S. Robinson, R. D. Schlichting, L. Simoncini, B. Smith,
L. Strigini, Y. Tohma, U. Voges, Y. W. Yang*

Volume 7

Springer-Verlag Wien New York

H. Kopetz, Y. Kakuda (eds.)

*Responsive
Computer Systems*

Springer-Verlag Wien New York

Prof. Hermann Kopetz, Technische Universität Wien, Austria
Dr. Yoshiaki Kakuda, Osaka University, Japan

With 96 Figures

This work is subject to copyright.
All rights are reserved,
whether the whole or part of the material is concerned,
specifically those of translation, reprinting, re-use of illustrations,
broadcasting, reproduction by photocopying machines or similar means,
and storage in data banks.
© 1993 by Springer-Verlag/Wien
Softcover reprint of the hardcover 1st edition 1993

Printed on acid-free paper

ISSN 0932-5581

ISBN-13: 978-3-7091-9290-0

e-ISBN-13: 978-3-7091-9288-7

DOI: 10.1007/978-3-7091-9288-7

FOREWORD

For the second time the International Workshop on Responsive Computer Systems has brought together a group of international experts from the fields of real-time computing, distributed computing, and fault-tolerant systems. The two day workshop met at the splendid facilities at the KDD Research and Development Laboratories at Kamifukuoka, Saitama, in Japan on October 1 and 2, 1992. The program included a keynote address, a panel discussion and, in addition to the opening and closing session, six sessions of submitted presentations.

The keynote address "The Concepts and Technologies of Dependable and Real-time Computer Systems for Shinkansen Train Control" covered the architecture of the computer control system behind a very responsive, i.e., timely and reliable, transport system—the Shinkansen Train. It has been fascinating to listen to the operational experience with a large fault-tolerant computer application. "What are the Key Paradigms in the Integration of Timeliness and Reliability?" was the topic of the lively panel discussion. Once again the pro's and con's of the time-triggered versus the event-triggered paradigm in the design of a real-time systems were discussed. The eighteen submitted presentations covered diverse topics about important issues in the design of responsive systems and a session on progress reports about leading edge research projects. Lively discussions characterized both days of the meeting.

This volume contains the revised presentations that incorporate some of the discussions that occurred during the meeting. Since it is hardly possible to record the engaged discussions without interrupting the flow of the arguments during the event, the interested reader is invited to attend the Third Workshop on Responsive Systems, to be held in New Hampshire from September 28 to October 1, 1993, if he/she wants to get the full spirit of the meeting.

At this point we would like to express our gratitude to the members of the program committee who have carefully reviewed the submitted papers. We would also like to thank the General Chairman, Tohru Kikuno and Mirsolaw Malek for their expert guidance and dedicated support of the Program Committee. If the work can be measured by the number of e-mail interactions during the preparation of this meeting, here is a short statistics. There exchanged 161 messages between University of Texas at Austin and Osaka University for organization of

the workshop and 75 messages between Technical University of Vienna and Osaka University for determination of the technical program.

Last but not least, special thanks are due to staff members of *KDD R&D* Laboratories, especially Hironori Saito, for their endless efforts and dedication to making the workshop successful, Yukio Mohri, *NihonUnisysLtd.* for his outstanding job in the production of the workshop proceedings, and Hideki Yunitomo, a graduate student of Osaka University, for his excellent work in reformatting the papers for this volume.

Hermann Kopetz
Program Co-Chair
Technical University of Vienna
Austria

Yoshiaki Kakuda
Program Co-Chair
Osaka University
Japan

Sponsors

IEEE Computer Society Technical Committee on *Fault-Tolerant Computing*
 IEEE Computer Society Technical Committee on *Real-Time Systems*
 IEICE Technical Group on *Fault-Tolerant Systems*
 International Communications Foundation
 International Information Science Foundation
 Kokusai Denshin Denwa Co., Ltd. (KDD)
 U. S. Office of Naval Research

Conference Organization

General Co-Chairmen

Mirosław Malek	Tohru Kikuno
University of Texas at Austin	Osaka University
USA	Japan

Program Co-Chairmen

Hermann Kopetz	Yoshiaki Kakuda
Technical University of Vienna	Osaka University
Austria	Japan

Session Chairs

Donald Fussell	Haruhisa Ichikawa
University of Texas at Austin	NTT
Austin, Texas, USA	Japan
Yoshiaki Kakuda	Gary Koob
Osaka University	ONR
Toyonaka, Osaka, Japan	USA
Hermann Kopetz	Insup Lee
Technical University of Vienna	University of Pennsylvania
Vienna, Austria	USA
Mirosław Malek	Kinji Mori
University of Texas at Austin	Hitachi Co.
Austin, Texas, USA	Japan

Program Committee

Tom Anderson
University of Newcastle
UK

Flaviu Cristian
University of California at San Diego
USA

Haruhisa Ichikawa
NTT
Japan

Gerard Le Lann
INRIA
France

Gary Koob
ONR
USA

Al Mok
University of Texas at Austin
USA

Sachio Naito
Tokyo Metropolitan University
Japan

Fabio Panzieri
University of Bologna
Italy

David Powell
LAAS-CNRS
France

Krithi Ramamritham
University of Massachusetts
USA

Lui Sha
Carnegie Mellon University
USA

Yoshihiro Tohma
Tokyo Institute of Technology
Japan

Mario Tokoro
Keio University
Japan

Yoshiyori Urano
KDD
Japan

Paulo Verissimo
INESC
Portugal

Contents

Opening Session	1
Six Difficult Problems in the Design of Responsive Systems <i>H. Kopetz (Technical University of Vienna, Austria)</i>	3
Issues in Responsive Protocols Design <i>Y. Kakuda, T. Kikuno (Osaka University, Japan)</i>	17
Responsive Systems Theory	27
A Probabilistic Duration Calculus <i>Z. Liu (University of Warwick, Coventry, UK)</i> <i>A. P. Ravn, E. V. Sørensen</i> <i>(Technical University of Denmark, Lyngby, Denmark)</i> <i>C. Zhou (United Nations University, Macau)</i>	29
Timed Statecharts and Real Time Logic <i>L. Barroca (University of York, York, UK)</i>	53
Fault-Tolerant Distributed Sort Generated from a Verification Proof Outline <i>H. Lutfiyya (University of Western Ontario, Canada)</i> <i>M. Schollmeyer, B. McMillin (University of Missouri-Rolla, USA)</i>	71
Responsive Protocols	97
Towards a Responsive Network Protocol <i>A. Shionozaki (Keio University, Japan)</i> <i>M. Tokoro (Sony Computer Science Laboratory, Japan)</i>	99
Fault-Tolerant Object by Group-to-Group Communications in Distributed Systems <i>H. Higaki, T. Soneoka (NTT, Japan)</i>	123

Space-Time Tradeoff in Hierarchical Routing Schemes <i>K. Ishida (Hiroshima Prefectural University, Japan)</i>	147
Work in Progress	165
Fault-Tolerance Support for Responsive Computer Systems <i>R. D. Schlichting (The University of Arizona, USA)</i>	167
Position Paper: Responsive Airborne Radar Systems <i>L. Sha, J. Lehoczky, M. Bodson (SEI/CMU, USA)</i> <i>P. Krupp, C. Nowacki (The MITRE Corp.)</i>	179
Overview of an Integrated Toolset Under Development for the CSR Paradigm <i>I. Lee, S. Davidson (University of Pennsylvania, USA)</i>	189
A Distributed Snapshots Algorithm and its Application to Protocol Stabilization <i>K. Saleh (Concordia University, Canada)</i> <i>H. Ural (University of Ottawa, Canada)</i> <i>A. Agarwal (Concordia University, Canada)</i>	197
Protocol Validation Tool and Its Applicability to Responsive Protocols <i>H. Saito, T. Hasegawa (KDD R & D Laboratories, Japan)</i>	207
Keynote Address	223
The Concepts and Technologies of Dependable and Real-time Computer Systems for Shinkansen Train Control <i>A. Hachiga (Railway Technical Research Institute, Japan)</i>	225
Real-Time Systems	253
Exception Handling in Real-Time Software from Specification to Design <i>R. de Lemos, A. Saeed, A. Waterworth</i> <i>(University of Newcastle upon Tyne, UK)</i>	255

Realizing Changes of Operational Modes with a Pre Run-Time Scheduled Hard Real-Time System <i>G. Fohler (Technical University of Vienna, Austria)</i>	287
Formal Specification and Simulation of a Real-Time Concurrency Control Protocol <i>P. van der Stok, L. Somers, P. Thijssen (Eindhoven University of Technology, Netherlands)</i>	301
Panel Discussion	319
What Are the Key Paradigms in the Integration of Timeliness and Availability ? <i>F. Cristian (University of California San Diego, USA)</i>	321
Contribution to the Panel: What are the Key Paradigms in the Integration of Timeliness and Availability <i>G. Le Lann (INRIA, France)</i>	327
Complicated Paradigm of Responsive Systems <i>Y. Tohma (Tokyo Institute of Technology, Japan)</i>	331
Toward Responsive Distributed Systems <i>M. Tokoro (Sony Computer Science Laboratory, Japan)</i>	335
Responsive System Design	337
A Reconfigurable Parallel Processor Based on a TDLCA Model <i>M. Tsunoyama (Nagaoka College of Technology, Japan)</i> <i>M. Kawanaka (NEC Robotics Engineering Ltd, Japan)</i> <i>S. Naito (Tokyo Metropolitan University, Japan)</i>	339
A Modeling Approach for Dynamically Reconfigurable Systems <i>H. de Meer, H. Mauser (University of Erlangen-Nuremberg, Germany)</i>	357
Author Index	377