Carnegie Mellon University
Software Engineering Institute

A Practitioner's Handbook for Real-Time Analysis

Guide to Rate Monotonic Analysis for Real-Time Systems

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Springer Science+Business Media, LLC

Library of Congress Cataloging-in-Publication Data

A Practitioner's handbook for real-time analysis : guide to rate monotonic analysis for real-time systems / Mark Klein ... [et al.].
p. cm. -- (The Kluwer international series in engineering and computer science. Real-time systems)
At head of title: Carnegie-Mellon University, Software Engineering Institute.
Includes bibliographical references and index.
ISBN 978-1-4613-6209-8 ISBN 978-1-4615-2796-1 (eBook)
DOI 10.1007/978-1-4615-2796-1
1. Real-time data processing. 2. System analysis. I. Klein, Mark. II. Carnegie-Mellon University. Software Engineering Institute. III. Series.
QA76.54.P73 1993
005.2--dc20 93-10744
CIP

Originally published by Kluwer Academic Publishers in 1993
Softcover reprint of the hardcover 1st edition 1993

Printed on acid-free paper.

This printing is a digital duplication of the original edition.

THE KLUWER INTERNATIONAL SERIES IN ENGINEERING AND COMPUTER SCIENCE

The Software Engineering Institute Real-Time Handbook Series

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Preface

About This Book

This handbook contains a collection of quantitative methods that enable real-time system developers to understand, analyze, and predict the timing behavior of many real-time systems. The methods are practical and theoretically sound, and can be used to assess design tradeoffs and to troubleshoot system timing behavior. We call this collection of methods **rate monotonic analysis** (RMA).

This handbook has been created to serve as a definitive source of information and a guide for real-time developers as they analyze and design real-time systems.

RMA Originated with Rate Monotonic Scheduling Theory

A theoretical treatment of fixed-priority scheduling first appeared in 1973 when Liu and Layland [Liu 73] introduced the **rate monotonic scheduling algorithm** for independent periodic tasks. The term **rate monotonic** comes from a method of assigning priorities to a set of tasks in which priorities are assigned as a monotonic function of the rate of a periodic task: the higher the rate, the higher the priority. Given this simple rule for assigning priorities, Liu and Layland demonstrated properties for certain tasks when task deadlines coincide with the end of a task's period.

Theoretical Foundation of RMA

Rate monotonic scheduling theory has been extended from its original form of scheduling independent periodic tasks [Liu 73] to scheduling

- Both periodic and aperiodic tasks [Sprunt 89a].
- Tasks with synchronization requirements [Rajkumar 88], [Rajkumar 90], [Sha 90b].
- Tasks with mode change requirements [Sha 89a], [Tindell 92a].
- Tasks with deadlines before the end of the period [Leung 82].

- Tasks with deadlines after the end of the period [Lehoczky 90].

In addition, the following issues have been addressed:

- Precise algorithms for determining schedulability [Joseph 86], [Lehoczky 89], [Audsley 90], [Lehoczky 90], [Audsley 91], [Harbour 91], [Tindell 92c], [Audsley 93].
- Associated hardware scheduling support [Lehoczky 86], [Sha 90c].
- Implications for Ada scheduling rules [Goodenough 88].
- Algorithm implementation in an Ada runtime system [Borger 89].
- Schedulability analysis of input/output paradigms [Klein 90].

Furthermore, design and analysis experiments have been performed to test the viability of the theory [Borger 89], [Locke 90]. Together, these findings constitute the set of analytical methods for real-time system engineering that we have named *rate monotonic analysis.*

RMA Assistance Available

We hope that you find RMA useful in designing, developing, and analyzing real-time systems, and we hope that this handbook facilitates your use of RMA. If you need information about a topic that is not covered or if there is a topic that you do not understand, we encourage you to contact Customer Relations at the Software Engineering Institute (SEI). The SEI will be happy to forward your question to an RMA consultant who will contact you as soon as possible.

Preface (Cont'd)

Suggestions for Improving the Handbook

In addition to providing a channel for assisting the readers of this book, we also would appreciate suggestions for improvement. If you find an error or omission, or have ideas for improving the clarity or usefulness of the handbook, please forward these to SEI Customer Relations.

Point of Contact

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Improvements

For a list of the improvements reflected in this printing, please contact SEI Customer Relations.

Acknowledgments

The authors gratefully acknowledge the contributions of the many people without whom this book would not have been possible.

The technology now known as rate monotonic analysis, upon which this book is based, had many key contributors. For a list of the important published findings in the field of rate monotonic analysis, please see the Bibliography.

We would like particularly to acknowledge the contributions of **Dr. Lui Sha** of the Software Engineering Institute and **Dr. John Lehoczky** of Carnegie Mellon University. With leadership, energy, and vision, Sha and Lehoczky transformed the fundamental findings of Liu and Layland [Liu 73] into a collection of methods and algorithms that we believe are of great value to real-time systems practitioners.

Dr. John B. Goodenough of the Software Engineering Institute has been the guiding force behind the transition of RMA technology into common practice. Goodenough's vision for RMA led directly to the Software Engineering Institute's RMA tutorials and to the production and ultimate publication of this handbook.

Jayne Cohen of Paramax contributed to the Glossary and provided an in-depth review of early drafts.

Reviewers

We further express our gratitude to the many people who were willing to take time from busy schedules to review and serve as test subjects for our early drafts: J. P. Rosen of ADALOG, France; Dr. Robert A. Brown of The Charles Stark Draper Laboratory, Inc.; Hassan Gomaa of George Mason University; Steve Vestal of Honeywell; Marion Moon of Hughes Aircraft; Dr. David Kirk, Thomas J. Mesler, and Dave Vogel of IBM; Pat Watson of IBM Federal Systems Co.; Tom McDermott of Lockheed Aeronautical Systems Co.; Steve Ignace, Don Kleinhans, Brian Newnam, Brian Pattison,

Acknowledgments (Cont'd)

and Steve Scheid of Magnavox; Milt Fulghum of McDonnell Douglas ESC; David B. Rodman of MITRE; Brad Clark, Mary Jo Haselhorst, Del Killian, Keith Kohout, Lee Lucas, Arlo Mickelsen, Bob Page, Tom Roseman, Bob Westbrook, and John Zenor of the Naval Air Warfare Center, China Lake; Bob Sedlmeyer and Dr. David J. Thuente of Indiana University-Purdue University, Ft. Wayne; Jim Murphy of Raytheon; John Hammer of Search Technology; Pat Rogers of Software Arts & Sciences; Patricia Brannigan, Larry Howard, Dr. Craig Meyers, Patrick Donohoe, Dr. Ragunathan Rajkumar, Michael Rissman, Rob Veltre, and Dr. Nelson Weiderman of the Software Engineering Institute; Mike Cochran and Richard A. Kirk of Software Productivity Consortium; Dwight Fohner of Sverdrup; Mr. Gentry Gardner of Telos Corporation; Stefan Fuchs of Universität Karlsruhe, Germany; Art Moorshead of Westinghouse; and John Barnes (consultant).

We also wish to thank those who attended the review session for our Beta edition: Godfrey Vassallo of Paramax; Russ Plain and Peter Kortmann of Tri-Pacific; and Dr. Gary Chastek of the Software Engineering Institute.

We would like to give a special thanks to those reviewers who tirelessly endured a review of the final version of the handbook: Dr. John B Goodenough, Lee Lucas, Dr. Ragunathan Rajkumar, Dr. David J. Thuente, and Dr. Nelson Weiderman. Thanks also to Dr. Daniel Katcher for help in correcting errors in the first printing.

Production and Editorial Assistants

At the Software Engineering Institute, Barbara Gratz and Barbara Zayas provided many hours of production and editorial assistance. Additional support was provided by Susan Abdalla, Daniel Bidwa, Todd Bowman, Pamela Burger-Hughes, Robert Lang, Mary McElhinney, Roberta Schwerer, Skip Shelly, and Mary Zoys.