

EATCS
Monographs on Theoretical Computer Science
Volume 13

Editors: W. Brauer G. Rozenberg A. Salomaa

Advisory Board: G. Ausiello M. Broy S. Even
J. Hartmanis N. Jones M. Nivat Chr. Papadimitriou
D. Scott



EATCS Monographs on Theoretical Computer Science

Vol. 1: K. Mehlhorn: Data Structures and Algorithms 1: Sorting and Searching. XIV, 336 pages, 87 figs. 1984.

Vol. 2: K. Mehlhorn: Data Structures and Algorithms 2: Graph Algorithms and NP-Completeness. XII, 260 pages, 54 figs. 1984.

Vol. 3: K. Mehlhorn: Data Structures and Algorithms 3: Multi-dimensional Searching and Computational Geometry. XII, 284 pages, 134 figs. 1984.

Vol. 4: W. Reisig: Petri Nets. An Introduction. X, 161 pages, 111 figs. 1985.

Vol. 5: W. Kuich, A. Salomaa: Semirings, Automata, Languages. IX, 374 pages, 23 figs. 1986.

Vol. 6: H. Ehrig, B. Mahr: Fundamentals of Algebraic Specification 1. Equations and Initial Semantics. XI, 321 pages. 1985.

Vol. 7: F. Gécseg: Products of Automata. VIII, 107 pages, 18 figs. 1986.

Vol. 8: F. Kröger: Temporal Logic of Programs. VIII, 148 pages. 1987.

Vol. 9: K. Weihrauch: Computability. X, 517 pages. 1987.

Vol. 10: H. Edelsbrunner: Algorithms in Combinatorial Geometry. XV, 423 pages, 93 figs. 1987.

Vol. 11: J.L. Balcázar, J. Díaz, J. Gabarró: Structural Complexity I. IX, 191 pages, 57 figs. 1988.

Vol. 12: J. Berstel, C. Reutenauer: Rational Series and Their Languages. VIII, 151 pages. 1988.

Vol. 13: E. Best, C. Fernández C.: Nonsequential Processes. IX, 112 pages, 44 figs. 1988.

Eike Best César Fernández C.

Nonsequential Processes

A Petri Net View

With 44 Figures

Springer-Verlag
Berlin Heidelberg New York
London Paris Tokyo

Authors

Dr. Eike Best
Prof. César Fernández C.
GMD, Institut für Methodische Grundlagen
Schloß Birlinghoven
D-5205 St. Augustin 1, FRG

Editors

Prof. Dr. Wilfried Brauer
Institut für Informatik, Technische Universität München
Arcisstrasse 21, D-8000 München 2, FRG

Prof. Dr. Grzegorz Rozenberg
Institute of Applied Mathematics and Computer Science
University of Leiden, Niels-Bohr-Weg 1, P.O. Box 9512
NL-2300 RA Leiden, The Netherlands

Prof. Dr. Arto Salomaa
Department of Mathematics, University of Turku
SF-20500 Turku 50, Finland

Library of Congress Cataloging-in-Publication Data.

Best, Eike, 1951- Nonsequential processes : a Petri net view / Eike Best, César Fernández C.
p. cm.—(EATCS monographs on theoretical computer science ; v. 13) Bibliography: p.
Includes index.

ISBN-13: 978-3-642-73485-4 e-ISBN-13: 978-3-642-73483-0

DOI: 10.1007/978-3-642-73483-0

1. Petri nets. 2. Machine theory. I. Fernández C., César, 1937-. II. Title. III. Series.
QA267.B48 1988 511.3—dc 19 88-11725 CIP

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, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in other ways, and storage in data banks. Duplication of this publication or parts thereof is only permitted under the provisions of the German Copyright Law of September 9, 1965, in its version of June 24, 1985, and a copyright fee must always be paid. Violations fall under the prosecution act of the German Copyright Law.

© Springer-Verlag Berlin Heidelberg 1988
Softcover reprint of the hardcover 1st edition 1988

The use of registered names, trademarks, 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.

TO

MONIKA
DAVID
ROBERT
SIMON
BENJAMIN
ANDREAS
GUDRUN UND HERBERT

ORIANA
ORIANITA.
CÉSAR
CARLOS
CAROLINA
BUELI
OLGA Y CARLOS

WITH LOVE

Preface

The theory of Petri nets is a part of computer science whose importance is increasingly acknowledged. Many papers and anthologies, whose subject matter is net theory and its applications, have appeared to date. There exist at least seven introductory textbooks on the theory.

The present monograph augments this literature by offering a mathematical treatment of one of the central aspects of net theory: the modelling of concurrency by partially ordered sets. Occurrence nets – which are special nets as well as special partial orders – are proposed by net theory for this purpose. We study both the general properties of occurrence nets and their use in describing the concurrent behaviour of systems.

Occurrence nets may be contrasted with a more language-oriented approach to the modelling of concurrency known as arbitrary interleaving. We will discuss some connections between these two approaches. Other approaches based on partially ordered sets – such as the theory of traces, the theory of event structures and the theory of semiwords – are not considered in this book, in spite of the strong links between them and net theory.

The monograph addresses students in theoretical computer science, mathematicians interested in discrete mathematics, researchers in the area of Petri nets and related topics and professionals in the design of concurrent systems interested in theoretical background. The reader is assumed to have an elementary background in set theory and basic mathematics. Previous knowledge in Petri net theory would be advantageous but is not strictly necessary.

The book is divided into four chapters. Chapter 1 gives the introduction. Chapter 2 deals with general partial order theory and finishes with a specialisation of the theory to posets derived from occurrence nets. Chapter 3 introduces a basic class of Petri nets that may model systems and shows how occurrence nets may be used to represent their nonsequential processes. Chapter 4 shows how properties may be translated from a system to its processes and vice versa.

The logical structure of the book is as follows. Chapter 2 describes a variety of properties of partially ordered sets, ones which may be considered as basic for processes (Sections 2.1 and 2.2) and ones which are interesting for other reasons (Sections 2.3, 2.4 and 2.5). Chapter 3 shows how the behaviour of a system can be defined in terms of occurrence nets. In order to understand this definition, Sections 2.1 and 2.2 are prerequisite reading. In Chapter 4,

the properties studied in Sections 2.3, 2.4 and 2.5 are translated into system properties. Hence Sections 2.3, 2.4 and 2.5 (as well as Chapter 3) are required reading in order to understand Chapter 4.

Each chapter is concluded by a number of exercises. Some of them are immediate applications of the concepts defined in the chapter. Some others are extensions of, or recent results in, the theory. The exercises labelled by a star * are harder than the others. An appendix explains the notation used in the book. Another appendix contains a selection of references to the literature and to applications of the theory.

Our appreciation goes to Carl Adam Petri for his willingness to have long discussions about the subject of the book, for his continuous support and, of course, for providing the very subject in the first place. We are indebted to Agathe Merceron and to Raymond Devillers who contributed directly to the material presented in this book. A number of colleagues of our Institute have provided us with comments on all or parts of the manuscript; to all of them we are very grateful. We would also like to thank P.S.Thiagarajan who has given us very useful comments. Our gratitude also goes to two referees who have studied the manuscript carefully and have made valuable suggestions. We are indebted to Elisabeth Münch who has done the drawing of the figures. Last but not least, we thank Grzegorz Rozenberg and Springer-Verlag for making possible the publication of this monograph and for their support.

St. Augustin, February 1988

Eike Best
César Fernández C.

Contents

1	Introduction	1
2	Partially Ordered Sets	7
2.1	Introduction and Basic Definitions	7
2.2	Combinatorialness and Discreteness	9
2.3	N-density and K-density	19
2.4	D-continuity	33
2.5	Occurrence Posets	42
3	Petri Nets	55
3.1	Nets and Markings	55
3.2	Transition Rule and Occurrence Sequences	56
3.3	Occurrence Nets and Processes	61
3.4	Inductive Definition of Processes	66
3.5	Systems of Finite Synchronisation	71
4	Connections Between Systems and Processes	79
4.1	Introduction	79
4.2	K-density and Safeness	79
4.3	D-continuity and Frozen Tokens	81
4.4	A Closing Remark on Finite 1-safe Nets	89
	Bibliographical Notes	91
	Bibliography	99
	Notation and Terminology	105
	Index of Definitions	111