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To everything there is a season and a time to every purpose under heaven: (...) a time to cast away stones and a time to gather stones together. *Ecclesiastes* 3:1,5[a]

Preface

In the past decade, the formal theory of specification, verification, and development of real-time programs has grown from work of a few specialised groups to a real "bandwagon". Many eminent research groups have shifted their interests into this direction. Consequently, the research in real-time is now entering established research areas in formal methods, such as process algebra, temporal logic, and model checking. Many dragons that we believed were slain long ago have risen from their ashes in the real-time world. Real-time specification and programming is more detailed and complex and usually more demanding, hence good methodologies and theories with powerful possibilities for abstraction are very much needed. Real-time is pre-eminently the touchstone of your theory. The scope of this research now includes:

Models of time: Time models possess characteristics which may range broadly from partial to total ordering, from referencing to points to intervals, from dense or even continuous to discrete domains, they may differ in the set of allowed operations (on the time domain), and finally time may be linear or branching.

Execution models: The introduction of time gives rise to many specific models, with familiar distinctions such as interleaving versus true concurrency, synchrony versus asynchrony, communication mechanisms, and new aspects such as local versus global clocks and the relation between actions and time (e.g., zero duration actions). Attempts are made to abstract from these specific models and treat them as features within one framework.

Logics: Many different approaches exist to quantify temporal logic, e.g., by means of an explicit clock reference (GCTL, RTTL, XCTL, TPTL) or by introducing bounded operators (METRIC TL).

Languages: We mention OCCAM, Estelle, Esterel as imperative languages, Lustre and Signal as declarative, and Statecharts as a graphical language.

Theories: Proof systems for programming languages have been developed (Timed CSP, OCCAM), but also process algebras have entered the field of real-time theories (Timed CCS, ATP, ACPS).

Analysing the model: Problems ranging from simulation through executable temporal logics to model checking against temporal formulas are investigated.

Applications Digital watches, fighter planes, process control, discrete control of continuous systems are some of the more standard examples.

Apparently, the time was ripe to organise a workshop dedicated solely to the theory of real-time with the purpose of stepping back and viewing the results achieved as well as of considering the directions of the ongoing research. This volume contains the proceedings of such a workshop. We believe that it gives a representative picture of what is going on in this field worldwide, presented by eminent, active researchers. Considering the number of authors from the United States and the quality of their contributions we conclude with

pleasure that the theory of real-time is catching on there and that the area is also breaking new ground in the new world. The material presented in this volume was prepared by the lecturers, their co-authors, and some of the observers after the workshop took place – in this way the results of the discussions during the workshop could be reflected in the proceedings. We are very grateful to the lecturers and the other participants for making the workshop a scientific and social success. We wish to thank R. Gerth and R. Koymans for their help in suggesting speakers. We gratefully acknowledge the financial support from our funding agency, the Netherlands National Facility for Informatics (NFI). We thank the Eindhoven University of Technology for the technical organisation of the workshop and its financial support, in particular A. Heijligers for his kind and flexible cooperation. We thank Jozef Hooman, Ron Koymans, and Marieke Munter for their help in the preparation and the local organisation.

The REX project

The REX — **R**esearch and **E**ducation in Concurrent **S**ystems — project investigates syntactic, semantic and proof-theoretic aspects of concurrency. In addition, its objectives are the education of young researchers and, in general, the dissemination of scientific results relating to these themes. REX is a collaborative effort of the Leiden University (G. Rozenberg), the Centre for Mathematics and Computer Science in Amsterdam (J.W. de Bakker), and the Eindhoven University of Technology (W.P. de Roever), representing the areas of syntax, semantics and proof theory, respectively. The project is supported by the Netherlands National Facility for Informatics (NFI); its duration is approximately four years starting in 1988. The educational activities of REX include regular "concurrency days", consisting of tutorial introductions, presentations of research results, and lecture series of visiting professors. The research activities of the REX project include, more specifically:

a) Three subprojects devoted to the themes: syntax of concurrent systems, process theory and the semantics of parallel logic programming languages, high-level specification and refinement of real-time distributed systems.

b) Collaboration with visiting professors and post-doctoral researchers.

c)Workshops and Schools. In 1988 a school/workshop on "Linear Time, Branching Time and Partial Order in Logics and Models for Concurrency" was organised; in 1989 a workshop followed on "Stepwise Refinement of Distributed Systems" and in 1990 one on "Foundations of Object-oriented Languages"(FOOL). The proceedings of these workshops appeared in the LNCS series of the Springer Publishing Company. The workshop "Real-Time: Theory in Practice" continues this series in 1991. In 1992, a workshop is organised on "Semantics: Theory and Applications". The project closes in 1993 with the symposium "A Decade of Concurrency: Highlights and Perspectives", where the accomplishments of the project will be surveyed and a look into the future will be attempted as to (un)expected developments in the theory of concurrency.

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