Simulation and Model-Based Methodologies: An Integrative View

Edited by

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NATO ASI Series

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Springer-Verlag Berlin Heidelberg New York Tokyo 1984

Published in cooperation with NATO Scientific Affairs Division

Proceedings of the Nato Advanced Study Institute on Simulation and Model-Based Methodologies: An Integrative View held at Ottawa, Ontario/Canada, July 26–August 6, 1982

ISBN 3-540-12884-0 Springer-Verlag Berlin Heidelberg New York Tokyo
ISBN 0-387-12884-0 Springer-Verlag New York Heidelberg Berlin Tokyo

Printed in Germany

Printing: Beltz Offsetdruck, Hemsbach; Bookbinding: J. Schäffer OHG, Grünstadt
2145/3140-543210

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NATO ASI Series

Advanced Science Institutes Series

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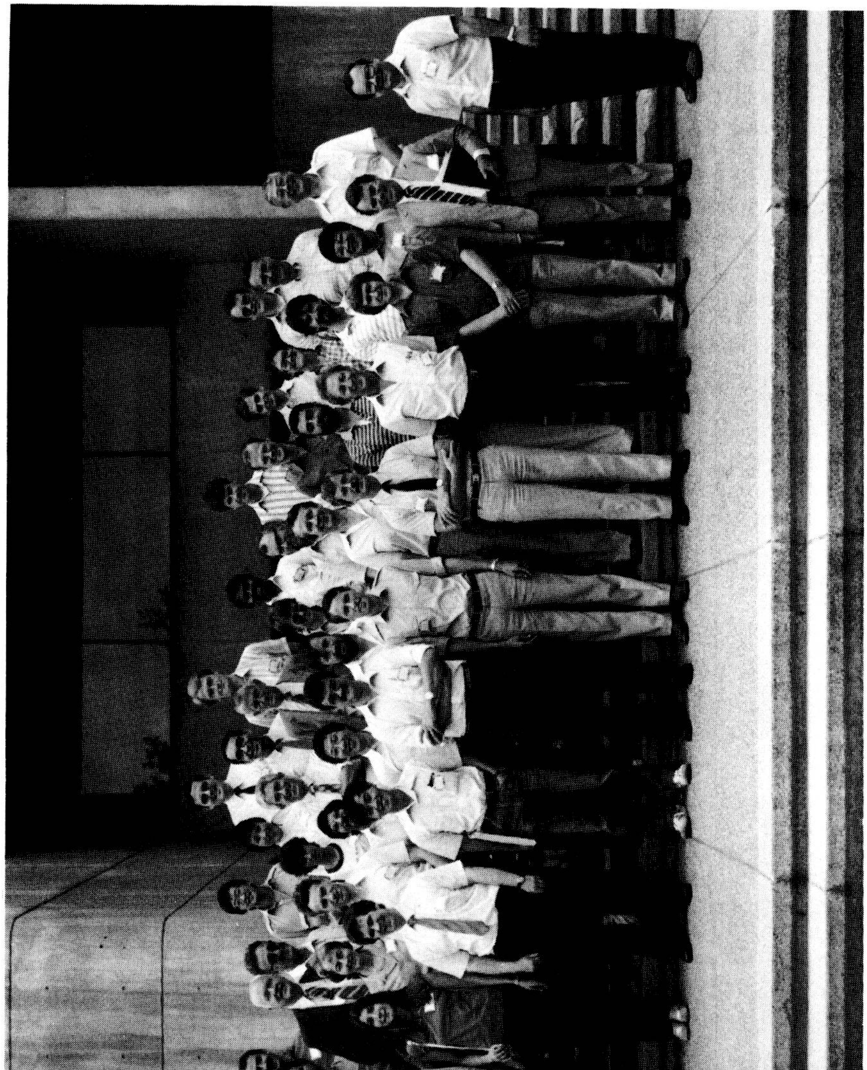
Series F: Computer and Systems Sciences Vol. 10



SYSTEM TRAVELLERS (AT TIME T)

Under the soft light
  of lamps at harbor

Travellers shared beautiful
  memories with each other

From all directions
  sailing as clouds
  gathering as stars
  searching for a goal of the univers

Tell me not
  tomorrow is far

Meet shall we
  in the endless wisdom sea
  Let us again sip our tea

Scholars with talents, knowledge
  and dreams indeed

Across the rainbow to the future
  may you succeed

Iris Chang

July 1982
NATO, ASI
Ottawa, Canada

FOREWORD

Simulation, like a gem, is multi-faceted. Several subfields of simulation have emerged based on the characteristics of **models** used in a simulation study, on the nature and the generation characteristics of model **behavior,** also on the **agent** such as a computer which generates model behavior.

For example, one distinguishes:

- deterministic simulation, stochastic simulation, stiff simulation based on **functional relationships of descriptive variables** of models used;
- combined simulation, continuous simulation, discrete simulation, process simulation, discrete event simulation, activity-scanning simulation based on **characteristics of descriptive variables of models;**
- variable topology simulation such as moving boundary simulation, cellular simulation and fixed topology simulation such as boundary-value simulation and network simulation (network flow simulation, Petri-net simulation, bond-graph simulation) based on **spatial distribution of models;**
- simulation with fixed organization models (such as simulation with hierarchical models) and simulation with variable organization models (i.e., autopoietic simulation) such as metamorphic simulation, simulation with self-organizating models, simulation with self-learning models, evolutionary simulation based on **organization of component models;**
- state-maintaining simulation, behaviorally adaptive simulation, goal-seeking simulation, purposive simulation, purposeful simulation, ideal-seeking simulation based on **goal(s) to be pursued by the model;**
- trajectory simulation, structural simulation, real-time simulation, predictive simulation, prescriptive simulation, intermittent simulation (such as regenerative simulation, optimizing simulation, gaming simulation, conferencing simulation, on-line simulation) based on **nature and generation characteristics of model behavior;** and
- simulators such as aircraft simulator, earthquake simulator where physical analog can be used to generate and/or display model behavior, and digital simulation, analog simulation and hybrid simulation, parallel simulation, simulation with array processors, and on-line simulation (such as interactive simulation, interpretive simulation, concurrent simulation, distributed simulation) based on **agent which generates model behavior.**

All the subfields of simulation share common methodological characteristics. Conception of simulation as a multifaceted field instead of an agglomeration of remotely related and often non-communicating numerous subfields is going to foster transfer of concepts, methodologies, and techniques among them, and thus tremendously contribute to the maturity of simulation and enhance its power and usefulness.

Viewed from another perspective, simulation shares also common traits with other fields such as operations research, decision support systems, and entity-relationship approach. All these fields are model-based; i.e., they rely on representation of knowledge as models. Ways to enhance the interface and transfer concepts and techniques among model-based fields may result in more powerful computerized decision tools.

Software and computer engineering, artificial intelligence, and simulation can contribute to each other. The enhancement and maturity of simulation has therefore strong ties with these disciplines.

The editors who were also the organizers of the NATO Advanced Study Institute held at the University of Ottawa in Ottawa, Ont. during July 26 - August 6, 1982 have strong committements to foster simulation to a more powerful decision tool.

The NATO Advanced Study Institute provided an excellent platform to gather select senior professionals from universities, research institutes and industry as well as young scientists and doctoral students to discuss and clarify concepts and problems which are germane to the many important fields that are based on the development and use of mathematical models. It is hoped that the basis provided will facilitate the transfer of knowledge among several domaines which specialize in model-based activities.

The book consists of six sections. First five sections consist of invited contributions by select professionals on 1) conceptual basis for system modelling and design, 2) model-based simulation architecture, 3) impact of formalisms on model formulation, 4) model identification, reconstruction, and optimization, and 5) quality assurance in model-based activities. Section 6 consists of contributed presentations in four of the workshops of the Institute.

I would like to take this opportunity to express my sincere appreciation to NATO officials notably to Dr. M. Di Lullo and Dr. B.A. Bayraktar for their valuable initial advice for the organization of the Institute and for their prompt and efficient handling all related matters.

In addition to the NATO officials, I would like to thank the members of Springer-Verlag for their understanding of the delay in the finalization of this book. Even though all the chapters and sections are invited contributions, they have been scrutinized by the editors and have been revised by their authors.

Last but not least, my appreciation and thanks to my wife Füsun for her understanding and help during the organization and running of the Institute as well in the editing of the book.

Tuncer I. Ören
Ottawa

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CONCEPTUAL BASES FOR SYSTEM MODELLING AND DESIGN

MODEL-BASED ACTIVITIES: A PARADIGM SHIFT*

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ABSTRACT

The aim of this chapter is to explore the possibilities to place simulation in a central position for several scientific disciplines. The following topics are discussed:

1) A proposed shift of paradigm in simulation,
2) Fundamental elements of a simulation study,
3) Models and behavior,
4) Synergies of simulation, software engineering, artificial intelligence, and general system theories,
5) Elements of a model-based simulation software system,
6) Knowledge-based modelling and simulation systems,
7) Highlights of desirable research directions in simulation methodology and software.

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* This study has been sponsored by the Natural Sciences and Engineering Research Council of Canada (NSERC) by the Operating Grant A8117.

NATO ASI Series, Vol. F10
Simulation and Model-Based Methodologies:
An Integrative View. Edited by T. I. Ören et al.

1. INTRODUCTION

Simulation, if viewed from the right perspective, can be a discipline central to many others. Knowledge about existing and conceived systems represented with their static and dynamic structures and expressed in computer processable forms leads to comprehensive knowledge processing abilities many of which are germane to computerized simulation.

In this chapter, to satisfy the aim of exploring the possibilities of placing simulation to a central position among several scientific disciplines, the following topics are discussed:

1) A proposed shift of paradigm in simulation,
2) Fundamental elements of a simulation study,
3) Models and behavior,
4) Synergies of simulation, software engineering, artificial intelligence, and general system theories,
5) Elements of a model-based simulation software system,
6) Knowledge-based modelling and simulation systems, and
7) Highlights of desirable research directions in simulation methodology and software.

2. SHIFT OF PARADIGM IN SIMULATION: NECESSITY AND EXPECTED BENEFITS

2.1 General

The way we perceive truth influences the domain of our actions. Furthermore, the development of science has witnessed several shifts of paradigms (Kuhn 1962). A systematization of the role of computer in model-based activities, within which simulation can be conceived as one of the possibilities, may be beneficial in several ways. Due to its versatility, simulation has been used in hundreds of application areas. It is not practical that a simulationist in one application area be knowledgeable in several other application areas. However, domain-independent aspects of simulation can be taught and shared by simulation methodologists and simulation users to avoid fixation with their own fields and to benefit from the useful concepts not yet readily available in their particular subfield.

Simulation as a field may benefit from a systematization of its own capabilities. This does not imply that all the possible features should be present in a given realization of a comprehensive modelling and simulation system. One can see the necessity of a systematization of model-based concepts applicable in simulation as a source of cross-fertilization of different subfields of simulation among themselves and of simulation with several related techniques or scientific disciplines.

As an example to a systematization of knowledge in a particular field one can consider Mendeleev's Periodic Table of the elements where characteristics of the known as well as unknown chemical elements are displayed in a systematic manner. Some of the elements were discovered after the realization of the Periodic Table of Elements.

An initial systematization of the concepts related with simulation was given in 1977 (Ören 1978c). A detailed systematization of the relevant concepts of simulation, model-management, and query systems may hopefully lead to the development of new, advanced, and useful possibilities for the usage of models.

2.2 Necessity and Some Expected Benefits

Simulation is experimentation with models (Korn and Wait 1978). However, the emphasis can be either on "experimentation" or on "models." I would propose that we conceive simulation as a special case of a more general and conceptually richer paradigm of model-based activities. This point of view might drastically facilitate conception of simulation as an integral part of several model-based activities in query systems. Thus, usage, usefulness, and domain of applicability of simulation could be drastically improved. Furthermore, application in simulation of concepts germane to some other model-related fields, could be facilitated to have fruitful cross-fertilization of some concepts.

Traditionally, the emphasis has been on experimentation and therefore on the generation of trajectories of descriptive variables. This view even though still useful in solving real problems, limited the use and usefulness of computerized simulation by creating several types of communication problems that can be grouped as follows:

Communication within the sub-cultures of simulation field:

For a Long time, simulation field has been divided into, basically non-communicating sub-fields some of which are:

- Digital versus analog and hybrid simulations: For a long-time the type of computer (i.e. analog, digital, hybrid) characterized and divided the users in different camps.