

# Real-Time Integration Methods for Mechanical System Simulation

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# Real-Time Integration Methods for Mechanical System Simulation

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## PREFACE

This book contains the edited versions of lectures and selected contributed papers presented at the NATO Advanced Research Workshop on Real-Time Integration Methods For Mechanical System Simulation, held in Snowbird, Utah, August 7-11, 1989. The Institute was attended by 42 participants from 9 countries, including leading mathematicians and engineers from universities, research institutions, and industry. The majority of participants presented either invited or contributed papers during the Institute, and everyone participated in lively discussions on scientific aspects of the program. The Workshop provided a forum for investigation of promising new directions for solution of differential-algebraic equations (DAE) of mechanical system dynamics by mathematicians and engineers from numerous schools of thought.

The Workshop addressed needs and opportunities for new methods of solving of DAE of mechanical system dynamics, from the perspective of a broad range of engineering and scientific applications. Among the most exciting new applications addressed was real-time computer simulation of mechanical systems that, for the first time in human history, permits operator-in-the-loop simulation of equipment that is controlled by the human; e.g., driving a vehicle, operating a space telerobot, operating a remote manipulator, and operating construction equipment. The enormous potential value of this new application and the fact that real-time numerical integration methods for DAE of mechanical system dynamics is the pacing problem to be solved in realizing this potential served to focus much of the discussion at the Workshop.

The Workshop was originally intended to provide a forum for examining promising new directions for the real-time solution of DAE of mechanical system dynamics. The present status of affordable computation restricts the numerical integration methods used for complex systems to only a few function evaluations and severely constrains the range of current DAE methods that are applicable in real-time simulation. At the conclusion of the Workshop, a consensus among the majority of participants was that such limitations will remain a serious challenge in applying the current generation of successful numerical methods for DAEs. Thus, the "Real-Time Integration Method" part of the Workshop is only in its initial development.

The unique mix of scholars in mathematics, numerical analysis, and engineering who participated in this Advanced Research Workshop created a rich multidisciplinary environment for consideration of new DAE methods and identification of new directions for research. The vigorous technical discussion that permeated the entire meeting, during lectures, meals, and informal evening meetings provided new insights that will focus the activity of leading research specialists in DAE methods.

This book is organized into three parts, each addressing a technical aspect of the field of DAE of mechanical system dynamics:

### Part 1 - DAE Applications and Basic Solution Methods

The first four papers provide an introduction to applications and formulation methods for dynamics of multibody systems. The remaining three papers in Part 1 provide an overview of the current state of the art in numerical solution of DAE, with a focus toward mechanical system dynamics.

## Part 2 - New DAE and ODE Solution Methods

The six papers comprising Part 2 present promising new methods for effective solution of DAE of mechanical system dynamics, including consideration of parallel computer solution of ordinary differential equations.

## Part 3 - Advanced DAE Applications

The five papers comprising Part 3 present a sampling of advanced applications that involve DAE of multibody dynamics and control.

The directors of the Workshop and editors of this text express their deep appreciation to NATO for sponsoring the Advanced Research Workshop; to the Evans & Sutherland Corporation for meeting preparation, local arrangements, and cordial support in conducting the Workshop; and to the lecturers and participants for their dedication and vigor throughout the Workshop. The pleasant surroundings of Snowbird, Utah created an invigorating environment for technical interaction and personal discussions.

While it is difficult to single out all persons who should receive formal thanks for making the Workshop and these Proceedings possible, a few must be noted. Ms. Vicky Roach of Evans & Sutherland tirelessly oversaw preparation for the Workshop and provided invaluable assistance throughout its conduct. Mr. Peter Doenges and Mr. John Briggs of Evans & Sutherland provided support throughout the Workshop. We also thank those employees of Evans & Sutherland who helped with transportation during the Workshop. Finally, Ms. Rozanne Huff and Ms. Pamela Ramser of the University of Iowa organized these Proceedings and prepared final manuscripts.

Edward J Haug  
Iowa City, Iowa  
May 1990

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Salt Lake City, Utah

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