CISM COURSES AND LECTURES NO. 487
INTERNATIONAL CENTRE FOR MECHANICAL SCIENCES

ROMANSY 16

ROBOT DESIGN, DYNAMICS, AND CONTROL

PROCEEDINGS OF THE SIXTEENTH CISM-IFToMM SYMPOSIUM

EDITED BY
TERESA ZIELIŃSKA
CEZARY ZIELIŃSKI

SpringerWienNewYork

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This volume contains 292 illustrations and 34 tables

Printed in Poland
SPIN 11791393

In order to make this volume available as economically and as rapidly as possible the authors' type scripts have been reproduced in their original forms. This method unfortunately has its typographical limitations but it is hoped that they in no way distract the reader.

ISBN 3-211-36064-6
ISBN 978-3-211-36064-4

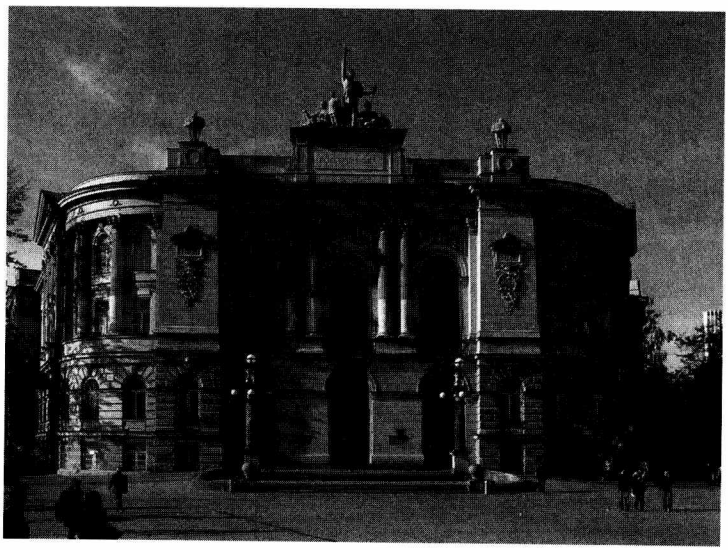
SpringerWienNewYork

CISM COURSES AND LECTURES

The series presents lecture notes, monographs, edited works and proceedings in the field of Mechanics, Engineering, Computer Science and Applied Mathematics.
Purpose of the series is to make known in the international scientific and technical community results obtained in some of the activities organized by CISM, the International Centre for Mechanical Sciences.

PREFACE

This volume contains the papers presented at the 16th Symposium on Theory and Practice of Robots and Manipulators, Warsaw, June 21–24, 2006. All papers had been reviewed by two independent reviewers before they were accepted for final publication and presentation at the Symposium. The event was organized under the supervision of international Steering Committee consisting of: M.Ceccarelli (IFToMM Secretary General, University of Cassino, Italy), I-Ming Chen (Nanyang Technological University, Singapore), B.Heimann (Chair of Technical Committee Robotics, Hannover University, Germany), E.Martin (Space Agency, Canada), O.Khatib (Stanford University, USA), W.Schiehlen (CISM representative, Technical University Munich, Germany), O.Takanishi (Waseda University, Japan), T.Zielińska (Warsaw University of Technology, Poland). Local Organizing Committee consisted of T.Zielińska, M.Olszewski, C.Zieliński, K.Kędzior from Warsaw University of Technology, K.Kozłowski from Poznań Technical University, and K.Tchoń from Wrocław Technical University. The symposium was held at the Faculty of Mechatronics, Warsaw University of Technology.



Main Building, Warsaw University of Technology

The 1st CISM-IFToMM Symposium on Theory and Practice of Robots and Manipulators was held on Sept. 5–8, 1973, in Udine, Italy, not long after IFToMM had been founded in 1969. The first ROMANSY, or Ro.Man.Sy, as the Symposium used to be referred to, marks the beginning of a long-lasting partnership between two international institutions, CISM, the Centre International des Sciences Mécaniques, and IFToMM, the International Federation for the Promotion of Mechanism and Machine Science. ROMANSY is one of the activities of IFToMM Technical

Committee for Robotics. The Symposium has taken place every even-numbered year with only one exception for the first symposium. It is traditionally a limited gathering of scientists that encourages informal discussions and focuses on recent trends and advances in robotics. The volume is organized into nine chapters with more than 50 papers in all. The Authors from 17 countries discussed the problems grouped in the following thematic parts:

— *Robot Design, Mechanism Performance,*
— *Motion Planning and Synthesis,*
— *Control Methods and Systems,*
— *Humanoids,*
— *Biology and Robotics – Specialized Tools and Methods,*
— *Innovative Technologies in Robotics,*
— *Space Robotics,*
— *Vision and Navigation.*

The key-note presentations dealt with the problems of the coexistence of humans and personal robots providing assistance to people in their housework, or to the elderly and the handicapped, as well as the robots working with or without human help in space missions. It is interesting that the cultural aspects influencing the robotics research also attracted the attention of the Scientists. Modeling and control methods of complex human-like robotic systems are developing very fast with the goal to produce a robot with human motion skills. To effectively work and cooperate with us, robots must exhibit abilities that are comparable to those of humans. The speakers focused on the ongoing efforts to design and develop human-friendly robotic systems that can safely and effectively interact and work with humans. The progress in robotics is also stimulated by human will to explore outer space. This issue creates specific requirements, limitations and targets for the designers. Standardization in space robots is necessary to enable the creation of advanced cooperative systems, where different technologies, requirements, control systems etc. meet. Finally, standardization is a critical element in having large numbers of robots working safely side-by-side their human counterparts.

*The 16th ROMANSY solicited papers providing a vision of the evolution of the robotics disciplines and identifying new directions in which these disciplines are foreseen to develop. The papers are devoted to novel robots, humanoids and bio-robotics problems, challenges in control and motion synthesis, kinematical and dynamical analysis of robotic systems, perception problems, space robots, and to other promising innovative mechanisms and technologies. We hope that the material included in this volume does not limit itself to just reporting the ongoing research, but will also stimulate the Reader to create new ideas and solutions, as: „**Every scientists is an artist and every artist is a scientist in a part**" (from: Summa Technologiae, by Stanisław Lem, 1964, Wydawnictwo Lubelskie).*

Warsaw, 20th May 2006

Teresa Zielińska
Cezary Zieliński

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Keynote Lectures

Humanoid Robotics, Culture and Society of Japan

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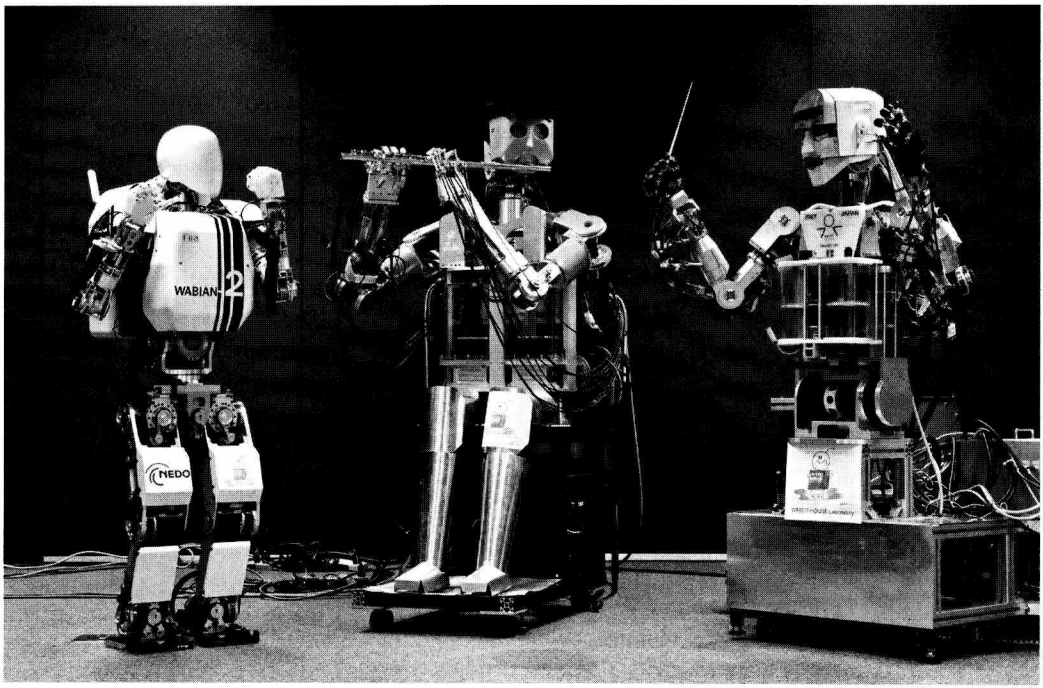
Japan

Even though the market size is still small at this moment, applied fields of robots are gradually spreading from the manufacturing industry to the others in recent years. One can now easily expect that applications of robots will expand into the first and the third industrial fields as one of the important components to support our society in the 21st century. There also raises strong anticipations in Japan that robots for the personal use will coexist with humans and provide supports such as the assistance for the housework, care of the aged and the physically handicapped, since Japan is one the fastest aging societies in the world. Consequently, humanoid robots and/or animaloid robots have been treated as subjects of robotics researches in Japan such as a research tool for human/animal science, an entertainment/mental-commit robot or an assistant/agent for humans in the human living environment. Over the last couple of years, some manufactures including famous global companies started to develop prototypes or even to sell mass production robots for the purposes mentioned above, such as TOYOTA, TMSUK, SONY, HONDA, Mitsubishi Heavy, ZMP, etc. Most of those robots have some life-likeness in their appearances and behaviors. Why are so many Japanese companies developing humanoid robots? I believe there is a special reason which strongly relates to the national character of Japan in terms of the history, the religion and the culture of Japan. On the other hand, Waseda University, where I belong to, has been one of the leading research sites on humanoid robot research since the late Prof. Ichiro Kato and his colleagues started the WABOT (WAseda roBOT) Projects and developed the historical humanoid robots that are WABOT-1 and WABOT-2 done in the early 70s and 80s respectively. One of the most important aspects of our research philosophy is as follows: By constructing

anthropomorphic/humanoid robots that function and behave like a human, we are attempting to develop a design method of a humanoid robot having human friendliness to coexist with humans naturally and symbiotically, as well as to scientifically build not only the physical model of a human but also the mental model of it from the engineering view point. Based upon the philosophy, I and my colleagues have been doing researches on humanoid robots, such as the Biped Walking Robots, Emotion Expression Robots, Mastication Robots, Flute Player Robots, Speech Production Robots, etc. In this plenary speech, I will introduce the national character of Japan in terms of the historical, religious and cultural backgrounds of Japan, as well as the research philosophy of humanoid robotics, the design concept of the humanoid robots and its applications with the robots mentioned above as examples.



The Human Frontier: Robotics New Quest and Challenge

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Summary

Robotics is rapidly expanding into human environments and vigorously engaged in its new emerging challenges. Interacting, exploring, and working with humans, the new generation of robots will increasingly touch people and their lives. The successful introduction of robots in these environments will rely on the development of competent and practical systems that are dependable, safe, and easy to use. To effectively work and cooperate with a person, robots must display abilities and skills that are compatible with those of humans. The discussion focuses on the ongoing effort for the design and development of human-friendly robotic systems that can safely and effectively interact and work with humans.

A major component in these developments is a new framework for the modeling and control of complex human-like robotic systems. In this framework, the various problems associated with (i) the motion coordination of the large number of degrees of such robots; (ii) the effective control of their contacts and interactions with the environment; (iii) the maintenance of their internal and external constraints; (iv) and the strategies for dealing with their underactuation and balance are all treated in a unified fashion within a general whole-body control structure. This is a task-oriented control structure that addresses the whole body dynamics for specifications involving multiple distributed tasks and postures in consistency with the requirements of multiple distributed contacts and constraints.

The second component in this effort is concerned with the synthesis of natural human movements to produce human-like robot behaviors. The objective is to unveil the underlying characteristics of human motion through an elaboration of its physiological basis. The aim is to formulate general strategies for whole-body robot behaviors. This exploration has employed models of human musculoskeletal dynamics and made use of extensive experimental studies of human subjects with motion capture techniques. Our

study of human motion has revealed the dominant role physiology plays in shaping human motion. The characteristics of human motion revealed in this study have allowed the development of generic motion creteria that efficiently and effectively encode human motion behaviors.

The third component in our effort is concerned with the critical issue of safety in robot design. Our work in human-friendly robot design has led to the development of a new actuation methodology which has been shown to be well-suited for the emerging generation of robots conceived to operate in human environments. This methodology of distributed macro mini actuation, DM^2, addresses both the safety and performance characteristics of a robot. The approach has led to the design and construction of several prototypes, the last of which is a two-arm on a common torso robotic testbed. This new system represents a unique platform to explore the competing issues of safety and performance in the design of robot mechanisms. The new two-arm torso testbed is being used to validate the promise of safety and performance and to establish meaningful measures for safety and performance. Of particular interest is the analysis of impact forces in a three dimensional collision between a robot and its surroundings. Two safety standard measures are used to quantify the improvement in safety in terms of reduction of impact force, while the robot performance characteristics are evaluated against traditional design.

Other fundamental issues in human-centered robotics will be also examined in this presentation. These include the elastic planning methodology for real-time modifications of existing plans, and various other effective methodologies and efficient algorithms that address the computational challenges associated with human-like robotic structures.