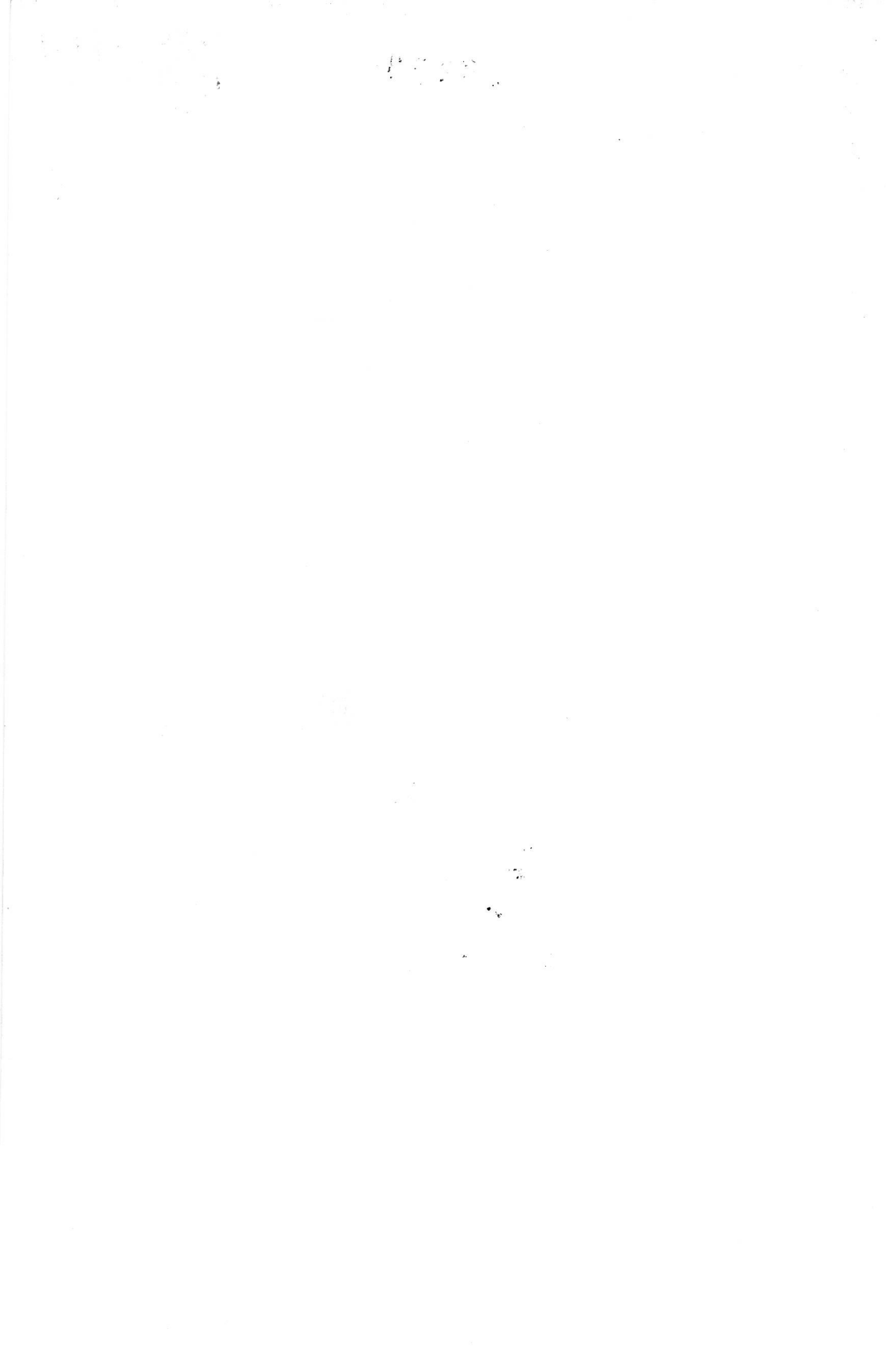




# **Theory and Practice of Robots and Manipulators**

**Proceedings of RoManSy '84:  
The Fifth CISM-IFToMM Symposium**



TP242

TP242-53

T396

1985

8662539

T396

1985

X

# Theory and Practice of Robots and Manipulators

Proceedings of RoManSy '84:  
The Fifth CISM-IFTOMM Symposium

Edited by  
A Morecki, G Bianchi and K Kędzior

*Sponsored by the CISM-Centre International des Sciences Mécaniques IFTOMM-International  
Federation for the Theory of Machines and Mechanisms in association with the IVth Technical  
Division of the Polish Academy of Sciences*

*Co-sponsored by the Institute for Aircraft Engineering and Applied Mechanics, Technical  
University of Warsaw*



E8662539



Kogan Page, London  
Hermes Publishing



0765085

First published 1985 by Kogan Page Ltd,  
120 Pentonville Road, London N1 9JN  
and Hermes Publishing, 51 rue Rennequin,  
75017 Paris, France

Copyright © 1985 RoManSy and contributors  
All rights reserved

**British Library Cataloguing in Publication Data**

Symposium on the Theory and Practice of Robots  
and Manipulators (5th: 1985)  
RoManSy '84: proceedings of the 5th Symposium  
on the Theory and Practice of Robots and  
Manipulators.  
1. Robots, Industrial  
I. Title II. Morecki, A. III. Bianchi, G.  
IV. Kedzior, K.  
629.8'92 TS191.8

ISBN 1 85091 016 2

Printed in Great Britain by The Anchor Press Ltd  
and bound by William Brendon and Son Ltd  
both of Tiptree, Essex



## Contents



Preface .....	11
Editorial Note .....	13
<b>Part 1 Opening Lecture</b> .....	<b>15</b>
Biomechanical Aspects in Robotics .....	17
<i>A Morecki and K Kędzior</i>	
<b>Part 2 Mechanics</b> .....	<b>23</b>
Coordinate Transformations and Inverse kinematics for Industrial Robots .....	25
<i>M S Konstantinov, P Y Genova, V B Zamanov, S P Patarinski and D N Nenchev</i>	
Industrial Robots with Recuperation of Mechanical Energy .....	31
<i>K V Frolov, A I Korendiasev, B L Salamandra and L I Tyves</i>	
On the Optimal Selection and Placement of Manipulators .....	39
<i>V Scheinman and B Roth</i>	
On the Geometry of Orthogonal and Reciprocal Screws .....	47
<i>H Lipkin and J Duffy</i>	
Trajectory Planning for Redundant Manipulators in the Presence of Obstacles .....	57
<i>M Kirćanski and M Vukobratović</i>	
Implementation of Highly Efficient Analytical Robot Models on Microcomputers .....	65
<i>M Vukobratović and N Kirćanski</i>	
Computer-aided Generation of Multibody-system Equations .....	73
<i>R Schwertassek and R E Roberson</i>	
Equations of Motion and Equations of Stress for Robots and Manipulators: An Application of the NEWEUL Formalism .....	79
<i>E J Kreuzer and W O Schieblen</i>	
Modelling of Artificial Manipulators and Computer Simulation of their Dynamics .....	87
<i>T Kawase, H Nakano and R Magoshi</i>	
Dynamics of Robots and Manipulators Involving Closed Loops .....	97
<i>T R Kane and H Faessler</i>	

<b>Part 3 Control of Motion</b>	<b>107</b>
Non-adaptive Dynamic Control for Manipulation Robots:	
Invited Survey Paper . . . . .	109
<i>M Vukobratović and D Stokić</i>	
Robot Motion Control in Multi-operation assembly . . . . .	123
<i>D E Okhotsimsky and S S Kamynin</i>	
Some Considerations on Feedback Strategy for Assembly	
Robots . . . . .	127
<i>J-P Merlet</i>	
Optimal Dynamic Trajectories for Robotic Manipulators. . . . .	133
<i>S Dubowsky and Z Shiller</i>	
Approximative Models in Dynamic Control of Robotic	
Systems. . . . .	145
<i>M Vukobratović and D Stokić</i>	
Keyboard Playing by an Anthropomorphic Robot:	
Fingers and Arm Model and its Control System of WAM-7R . . . . .	153
<i>S Sugano, J Nakagawa, Y Tanaka and I Kato</i>	
Control of Two Co-ordinated Robots by Using an Only-	
kinematic Model . . . . .	163
<i>P Dauchez, A Fournier and R Zapata</i>	
A Method for Time-optimal Control of Dynamically	
Constrained Manipulators . . . . .	169
<i>P Kiriazov and P Marinov</i>	
Bracing Strategy for Robot Operation . . . . .	179
<i>W J Book, S Le and V Sangveraphunsiri</i>	
Robot Control and Computer Languages . . . . .	187
<i>R P Paul and V Hayward</i>	
Robust Control for Industrial Robots . . . . .	195
<i>H Bremer and A Truckenbrodt</i>	
Controlling a Six-degrees-of-freedom Welding Robot along	
a Randomly Oriented Seam with Reduced Sensor	
Information . . . . .	205
<i>A Micaelli and J M Détriché</i>	
Principles and Algorithms for Industrial Robots Remote	
Automatic Control . . . . .	215
<i>V S Kuleshov, Yu V Poduraev and V N Shvedov</i>	
 <b>Part 4 Man-Intelligent Machine Systems</b>	 <b>221</b>
Manual Control Communication in Space Teleoperation. . . . .	223
<i>A K Bejczy and K Corker</i>	
Sensory-based Control for Robots and Teleoperators . . . . .	233
<i>B Espiau and G Andre</i>	
Tele-existence (I): Design and Evaluation of a Visual	
Display with Sensation of Presence . . . . .	245
<i>S Tachi, K Tanie, K Komoriya and M Kaneko</i>	
New Approach to Robotic Visual Processing. . . . .	255
<i>B Macukow</i>	

Representing Three-dimensional Shape . . . . .	261
<i>M Brady and A Yuille</i>	
An Electropneumatic Actuation System for the Utah/MIT Dextrous Hand . . . . .	271
<i>S C Jacobsen, D F Knutti, K B Biggers, E K Iversen and J E Wood</i>	
Sensor-aided and/or Computer-aided Bilateral Teleoperator System (SCATS) . . . . .	281
<i>J Vertut, R Fournier, B Espiau and G Andre</i>	
<b>Part 5 Synthesis and Design</b>	<b>293</b>
Mechanical and Geometric Design of the Adaptive Suspension Vehicle . . . . .	295
<i>K J Waldron, S Song, S Wang and V J Vohnout</i>	
Geometrical and Kinematical Qualitative Characteristics for Functional Capacities of Manipulation Systems . . . . .	307
<i>L Lilov and B Bekjarov</i>	
Manipulation Devices Based on High-class Mechanisms . . . . .	313
<i>U A Djoldasbekov, L I Slutskii and J J Baiguncbekov</i>	
Synthesis and Design of Mechanical Hands for Robots with Application of Computer-aided Design . . . . .	321
<i>A Rovetta</i>	
A New Design Method of Servo-actuators Based on the Shape Memory Effect. . . . .	339
<i>S Hirose, K Ikuta and Y Umetani</i>	
Coverage Optimization of Articulated Manipulators . . . . .	351
<i>G Fraize, J Vertut and R Hugon</i>	
<b>Part 6 Biomechanics of Motion: Locomotion</b>	<b>363</b>
Study of Propelling Agents Construction Features of Orthogonal Walking Robots by Using Plane Mechanisms . . . . .	365
<i>V S Balbarov, A Bessonov and N V Umnov</i>	
A Hierarchically Structured System for Computer Control of a Hexapod Walking Machine . . . . .	375
<i>R B McGhee, D E Orin, D R Pugh and M R Patterson</i>	
Realization of Plane Walking by the Biped Walking Robot WL-10R . . . . .	383
<i>A Takanishi, G Naito, M Ishida and I Kato</i>	
Hexapod Walking Robots with Artificial Intelligence Capabilities . . . . .	395
<i>J J Kessiss, J P Rambaut, J Penné, R Wood and N Mattar</i>	
Legged Locomotion Machine Based on the Consideration of Degrees of Freedom . . . . .	403
<i>M Kaneko, M Abe, S Tachi, S Nishizawa, K Tanie and K Komoriya</i>	
Trotting and Bounding in a Planar Two-legged Model . . . . .	411
<i>K N Murphy and M H Raibert</i>	



<b>Part 7 Application and Performance Evaluation</b>	<b>421</b>
Determination of Important Design Parameters for Industrial Robots from the Application Point of View: Survey Paper . . . . .	423
<i>R D Schraft and M C Wanner</i>	
Automatic Assembly by Reference Searching and Position Adjustment before Insertion . . . . .	431
<i>F Artigue and C François</i>	
<b>Participants . . . . .</b>	<b>439</b>

## **Organizing and Programme Committee**

### **Chairman:**

Prof. G Bianchi

CISM, Piazza Garibaldi 18, 33100 Udine (Italy)

### **Vice Chairman:**

Prof. A Morecki

Warsaw Technical University, Al Niepodległości 222 r 206, 00-663 Warsaw  
(Poland)

### **Members:**

Prof. A P Bessonov

Academy of Sciences of the USSR, Griboedova Street 4, Moscow-Centre 101000  
(USSR)

Prof. I Kato

Waseda University, Faculty of Science and Engineering, Ookubo, Shiniuku-ku,  
Tokyo 160 (Japan)

Prof. A E Kobrynskii

Academy of Sciences of the USSR, Griboedova Street 4, Moscow-Centre 101000  
(USSR)

Prof. M S Konstantinov

Central Laboratory for Manipulators and Robots, Higher Institute of Mechanical  
and Electrical Engineering, 1156 Sofia, Darvenitza, PO Box 97 (Bulgaria)

Prof. H Rankers

Bedrijfsmechanisatie, Landbergstraat 3, 2628(E) Delft, (The Netherlands)

Prof. B Roth

Stanford University, Department of Mechanical Engineering, Stanford, CA 94305  
(USA)

Dr R D Schraft

Fraunhofer Institute for Production and Automation, University of Stuttgart,  
PO Box 951, Stuttgart (Federal Republic of Germany)

Dr J Vertut

Commissariat à l'Energie Atomique, BP no. 2, 91190 Gif-sur-Yvette (France)

Prof. J Volmer

Technische Hochschule, DDR-9010 Karl-Marx-Stadt, PSF 964 (German  
Democratic Republic)

Prof. M Vukobratović

Institute 'Mihailo Pupin', Volgina 15, PO Box 906 (Yugoslavia)

### **Scientific Secretary:**

Dr K Kędzior

Warsaw Technical University, Al Niepodległości 222 r 206, 00-663 Warsaw  
(Poland)

### **Secretary:**

Dr A Bertozzi

CISM, Piazza Garibaldi 18, 33100 Udine (Italy)



## Preface

The RO MAN SY Symposia have played an important role in the development of the theory and, to a lesser extent, the practice of manipulators, walking machines and robots.

Based on past experience of previous symposia, which have been held over the last 10 years, the problem arose as to what to do in the future. In other words, in what direction should further symposia be organized?

A panel discussion called 'Role of RO MAN SY Symposia' was held on 29 June 1984 during the final plenary session at CISM, Udine, Italy. The Members of the Organizing Committee, Professors Konstantinov, Morecki, Roth, Vukobratović and Vertut, and other participants were asked to give their opinions on the following important questions:

- should we organize future symposia?
- if we continue, which form should we choose?: small (60-70 participants, 35-40 invited papers); big (100-150 participants, 60-80 papers)
- what kind of topics should be included?: the more theoretical-oriented; more practical-oriented; both (what proportion?)
- how frequently should RO MAN SY Symposia be organized?: every other year; every third year
- what is working well and what should be maintained?
- what is not working well and what should be changed to increase the impact of the symposia?

I would like to underline that most of the participants agree that we should continue to hold our symposia every other year, but to limit their small form, with invited papers at high theoretical level only in mechanics, control of motion, synthesis and design, manipulation and locomotion and application and performance evaluation of manipulators and robots.

To improve the value of the symposia it is necessary to select for presentation only those papers which represent good new theoretical contributions and relate to the above-mentioned topics.

The survey papers, panel discussion and discussion following presentations should play an important role in future symposia.

I hope that this volume, which contains a set of papers presented during the latest symposium, will be welcomed by all those scientists who belong to the robotic family.

*Professor A Morecki*  
Chairman of the CISM-IFTToMM Technical Committee  
for Robots and Manipulators  
Warsaw, September 1984



## Editorial Note

This volume contains the papers accepted for the Fifth Symposium on Theory and Practice of Robots and Manipulators 'RO MAN SY '84' held in Udine, Italy, 26-29 June 1984.

'RO MAN SY '84' was attended by 65 participants from 14 countries (as listed) who were selected experts in the field of robotics.

The symposium programme included:

- Opening and closing sessions attended by CISM and IFToMM officials
- General lecture given by Professor A Morecki, Chairman of the CISM-IFToMM Technical Committee for Robots and Manipulators
- Working sessions (mechanics, control of motion, synthesis and design, biomechanics of motion-locomotion, man-intelligent machine systems, application and performance evaluation)
- Panel discussion 'Role of RO MAN SY Symposia' organized by Professor A Morecki
- Two film sessions.

The papers in this book are in the same sequence as the sessions mentioned above. All linguistic and terminology corrections have been kept to a minimum.

The proceedings of the previous four symposia are available in the final form. The proceedings of the 'RO MAN SY '73' (5-8 September 1973, Udine, Italy) may be obtained from Springer-Verlag, Vienna. Those of 'RO MAN SY '76' (14-17 September 1976, Jadwisin, Poland) and 'RO MAN SY '78' (12-15 September 1978, Udine, Italy) may be purchased from Elsevier Scientific Publishing Co. (Amsterdam) or PWN-Polish Scientific Publishers (Warsaw). Proceedings of the 'RO MAN SY '81' (8-12 September 1981, Zaborow, Poland) may be obtained from PWN (Warsaw).

The next symposium 'RO MAN SY '86' will be held in Poland in early September 1986.

*A Morecki, G Bianchi and K Kędzior*



# **Part 1**

## **Opening Lecture**



