

**2000 IEEE International Conference on
Robotics and Automation
(V.4) (V. A)**

7p242-53
R666
2000
V.4A

Proceedings

2000 I C R A

IEEE International Conference on Robotics and Automation

April 24 – 28, 2000
San Francisco Hilton Hotel
San Francisco, California

Sponsored by

IEEE Robotics and Automation Society

Volume 4

Pages 3071-4122



E200000985

ICRA 2000 PROCEEDINGS

Additional copies may be ordered from:

IEEE Service Center
445 Hoes Lane
P.O. Box 1331
Piscataway, NJ 08855-1331 U.S.A.

IEEE Catalog Number 00CH37065
ISBN 0-7803-5886-4 (Softbound)
ISBN 0-7803-5887-2 (Casebound)
ISBN 0-7803-5888-0 (Microfiche)
Library of Congress Catalog Number 90-640158
ISSN 1050-4729
IEEE Catalog Number (CD-ROM): 00CH37065C
ISBN 0-7803-5889-9 (CD-ROM)

Copyright and Reprint Permission:

Abstracting is permitted with credit to the source. Libraries are permitted to photocopy beyond the limit of U.S. copyright law for private use of patrons those articles in this volume that carry a code at the bottom of the first page, provided the per-copy fee indicated in the code is paid through Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For other copying, reprint, or republication permission, write to IEEE Copyrights Manager, IEEE Operations Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331. All rights reserved. Copyright ©2000 by the Institute of Electrical and Electronics Engineers, Inc.

The papers in this book comprise the proceedings of the meeting mentioned on the cover and title page. They reflect the author's opinions and, in the interest of timely dissemination, are published as presented and without change. Their inclusion in this publication does not necessarily constitute endorsement by the editors or the Institute of Electrical and Electronics Engineers, Inc.

Printed in the United States of America by OMNIPRESS.....The Proceedings Printer.

The Institute of Electrical and Electronics Engineers, Inc.

Foreword

The 2000 IEEE International Conference on Robotics and Automation, ICRA2000, held in San Francisco April 24-28, 2000, is the 17th in a series of annual conferences sponsored by the IEEE Robotics & Automation Society.

During the 20th century, the body of concepts, methods, and systems that we refer to as "Robotics and Automation" emerged as a major field. While its origins can be traced to the industrial revolution that began more than 150 years ago, it continues to evolve today. Now, at the dawn of the new millennium, robotics is undergoing a major transformation in scope and dimension. From a largely dominant industrial focus, robotics is rapidly expanding into the challenges of unstructured environments. Interacting with, assisting, serving, and exploring with humans, the emerging robots will increasingly touch people and their lives. These advances in intelligent machines will impact a wide range of areas in manufacturing, space, underwater, services, health care, entertainment, design, and automation, among others. The emphasis on these new frontiers is reflected in the theme for the 2000 Conference, Robotics and Automation: The Next Generation. The 2000 Conference provides a unique opportunity for researchers and engineers in our community to reflect on the field's accomplishments, new developments, and future directions.

Our goal for ICRA2000 was to develop a technical program with the highest quality in content and organization. In planning the conference, a special effort was made to create a conference structure that is conducive to quality interactions between participants. The structure, which is reflected in these Proceedings, provides for a reduced number of parallel tracks and includes, in addition to the regular tracks, a series of theme-oriented symposia. Organized by leading researchers in their respective fields, these symposia serve to present summaries of many of the sub-disciplines that comprise the field of robotics and automation. The 28 symposium sessions cover topics ranging from the field's foundations to the emerging applications of robotics and manufacturing automation.

The entire ICRA2000 Program consists of 111 technical sessions for a total of 641 papers chosen from the nearly 1100 submissions. The 641 selected papers, as a whole, stress the conference theme, which is further highlighted by four keynote presentations and two plenary sessions. The four keynote presentations are: "Vision – Enabling Robots to Sense, Control and Interact," by Takeo Kanade; "Controlling Intelligent Machines," by Hendrik Van Brussel; "Motion Planning: A Journey of Robots, Molecules, Digital Actors, and Other Artifacts," by Jean-Claude Latombe; and "Hands On: Haptics and Telesurgery," by Kenneth Salisbury. Organized by Georges Giralt, the two plenary sessions are entitled "Robotics: the 20th Century and Beyond" and "National and International R&D Projects and Programs." The Banquet address is given by Stephen Jacobsen. The program also includes a panel on Education, two video sessions, five tutorials, and nine workshops.

We would like to express our appreciation and thanks to all the members of the Organizing Committee, Technical Program Committee and Video Proceedings Committee for their efforts and contributions to the program and organization of this conference. Our special thanks go to the volunteers and staff for the long hours and hard work they have generously given to the conference. But above all, ICRA2000 is the result of the contributions of its authors. We would like to thank all the authors, speakers, participants, and organizers for taking part in and contributing to ICRA2000.

Brian Carlisle
General Chairman

Oussama Khatib
Program Chairman

ICRA2000

Organizing Committee

General Chair

Brian R. Carlisle, USA

Program Chair

Oussama Khatib, USA

Program Vice-Chairs

Ruzena Bajcsy, USA

Raja Chatila, France

John J. Craig, USA

Georges Giralt, France

Shigeo Hirose, Japan

Awards Co-Chairs

George Bekey, USA

T. J. Tarn, USA

Local Arrangements Chair

Machiel Van der Loos, USA

Advisory Committee Chair

Norman Caplan, USA

Tutorials and Workshops Chair

Ken Goldberg, USA

Finance Chair

Betsy Lange, USA

Video Proceedings Chair

Rajiv Dubey

Exhibits Chair

Amber Kluga, USA

Publications Co-Chairs

Christian Laugier, France

C.S. George Lee, USA

Publicity Chair

Dennis Gracanin, USA

Web Chair

T. Kesavadas, USA

Program Committee

Program Chair

Oussama Khatib

Program Vice Chairs

Ruzena Bajcsy, Raja Chatila, John Craig, Georges Giralt,
Shigeo Hirose

Asia/Oceania

Marcelo H. Ang, Jr.
Fumihito Arai
Minoru Asada
Hajime Asama
John Billingsley
Myung Jin Chung
Wankyun Chung
Peter Corke
Hugh Durrant-Whyte
Li-chen Fu
Toshio Fukuda
Hideki Hashimoto
Shigeo Hirose

Katsushi Ikeuchi
Hirochika Inoue
Ray Jarvis
Makoto Kaneko
Kazuhiro Kosuge
Yasuo Kuniyoshi
Beom-Hee Lee
Tong Heng Lee
Zexiang Li
Ren C. Luo
Brendan McCarragher
Hirofumi Miura
Yoshi Nakamura

Sang-Rok Oh
Julio Rosenblatt
Shigeki Sugano
Il Hong Suh
Atsuo Takanishi
Kazuo Tanie
James Trevelyan
N. Viswanadham
Yangsheng Xu
Yasuyoshi Yokokohji.
Tsuneo Yoshikawa
Shin'ichi Yuta

Europe/Mediterranean

Rachid Alami
Nicholas Ayache
Antonio Bicchi
Philippe Bidaud
Herman Bruyninckx
Alicia Casals
Jose A. Castellanos
Raja Chatila
Francois Chaumette
Eve Coste-Maniere
Jim Crowley
Paolo Dario
Pierre Dauchez
Alessandro DeLuca
Angel del Pobil
Joris Deschutter

Ruedigger Dillmann
Olav Egeland
Alberto Elfes
Aydan Erkmén
Bernard Espiau
Roy Featherstone
Georges Giralt
Alessandro Giua
Manfred Hiller
Gerd Hirzinger
Radu Horaud
Manfred Husty
Okyay Kaynak
Wisama Khalil
Krzysztof R. Kozłowski

Kostas Kyriakopoulos
Dave Lane
Christian Laugier
Jean-Paul Laumond
Jadran Lenarcic
Claudio Melchiorri
Jean-Pierre Merlet
Elon Rimon
Imre Rudas
Bruno Siciliano
Li Ning Sun
Jan Swevers
Spyros G. Tzafestas
Luigi Villani
Andre Zisserman

America

Sunil Agrawal
Hadi Akeel
Prasad Akella
Brian Armstrong
Harry Asada

Chris Atkeson
Harlyn Baker
Tucker Balch
Antal Bejczy
George Bekey

Beno Benhabib
Jim Bobrow
Bob Bolles
Wayne Book
Rodney Brooks

Program Committee - America (con't)

Joel Burdick	Yutaka Kanayama	Nancy Pollard
Martin Buss	Lydia Kavradi	Jean Ponce
John Canny	Kazuhiko Kawamura	Bernard Roth
Greg Chirikjian	Hami Kazerooni	Daniela Rus
Howie Choset	T. Kesavadas	Tim Salcudean
James Clark	Pradeep Khosla	Arthur Sanderson
John J. Craig	Richard Klafter	Nilanjan Sarkar
Jill Crisman	Dan Koditschek	Stefan Schaal
Mark Cutkosky	Antti Koivo	Hagen Schempf
Alan Desrochers	Reid Kress	Zvi Shiller
Steve Dubowsky	Vijay Kumar	Reid Simmons
Gregory Dudek	Steven LaValle	Tarek Sobh
David Falconer	C. S. George Lee	Anthony Stentz
Ron Fearing	Kok-Meng Lee	Gaurav Sukhatme
Paolo Fiorini	Sooyong Lee	Karim Tahboub
Bijoy K. Ghosh	John Leonard	Yu-Chong Tai
Ken Goldberg	John Luh	Tzyh-Jong Tarn
Andrew Goldenberg	Peter Luh	Russell Taylor
Kamal Gupta	Vladimir Lumelsky	Chuck Thorpe
Gregory Hager	Kevin Lynch	Jeff Trinkle
William Hamel	Anthony Maciejewski	Kimon Valavanis
Blake Hannaford	Matt Mason	Machiel Van der Loos
Vincent Hayward	Larry Matthies	Ken Waldron
Martial Hebert	Dinos Mavroidis	Dan Whitney
Jessica Hodgins	Michael McCarthy	Peter Will
Steve Holland	Robin Murphy	Ning Xi
John Hollerbach	David Musliner	Jing Xiao
Ralph Hollis	Shree Nayar	Kamal Youcef-Toumi
Roberto Horowitz	Bradley Nelson	Xiaobu Yuan
T.C. Steve Hsia	David Orin	Junku Yuh
Seth Hutchinson	Dinesh Pai	Xiaoping Yun
Abhinandan Jain	Nikolaos Papanikolopoulos	Yuan F. Zheng

Video Proceedings Committee

Video Proceedings Committee Chair

Rajiv Dubey

Video Proceedings Committee Members

I-Ming Chen, Singapore
T. Kesavadas, USA

Peter B. Luh, USA
Shigeki Sugano, Japan

Luigi Villani, Italy

Table of Contents

Foreword	iii
Organizing, Program and Video Committees	iv
Author Index	li

Volume 1 Symposium (Pages 1-970)

SYMPOSIUM: MOP1-4 (S) KINEMATICS

Kinematics' Not Dead!	1
<i>J.-P. Merlet</i>	
Self-Motions of Griffis-Duffy Type Parallel Manipulators	7
<i>Manfred L. Husty and Adolf Karger</i>	
Nonintrinsicity of References in Rigid Body Motions	13
<i>S. Stramigioli and H. Bruyninckx</i>	
Kinematic Transformations for Remotely-Actuated Planar Continuum Robots	19
<i>Ian A. Gravagne and Ian D. Walker</i>	
Kinematic Design of a Humanoid Robotic Shoulder Complex	27
<i>Jadran Lenarčič, Michael M. Stanišić and Vincenzo Parenti-Castelli</i>	

SYMPOSIUM: MOP1-5 (S) MECHANISMS

Coupled and Decoupled Actuation of Robotic Mechanisms	33
<i>Shigeo Hirose and Keisuke Arikawa</i>	
Scaling of Robotic Mechanisms	40
<i>Kenneth J. Waldron and Christopher Hubert</i>	
A Mechatronics Approach to the Design of Light-Weight Arms and Multifingered Hands	46
<i>G. Hirzinger, J. Butterfab, M. Fischer, M. Grebenstein, M. Hähne, H. Liu, I. Schaefer and N. Sporer</i>	
Mechanism Synthesis Theory and the Design of Robots	55
<i>J. Michael McCarthy</i>	
TerminatorBot: A Robot with Dual-Use Arms for Manipulation and Locomotion	61
<i>Richard M. Voyles</i>	

SYMPOSIUM: MOP1-6 (S) ARCHITECTURES

Architecture, the Backbone of Robotic Systems	67
<i>Ève Coste-Manière and Reid Simmons</i>	
Social Potentials for Scalable Multi-Robot Formations	73
<i>Tucker Balch and Maria Hybinette</i>	

PredN: Achieving Efficiency and Code Re-Usability in a Programming System for Complex Robotic Applications	81
<i>Olivier Stasse and Yasuo Kuniyoshi</i>	
Around the Lab in 40 Days	88
<i>Rachid Alami, Raja Chatila, Sara Fleury, Matthieu Herrb, Felix Ingrand, Maher Khatib, Benoit Morisset, Philippe Moutarlier and Thierry Siméon</i>	
Using Model Checking to Guarantee Safety in Automatically-Synthesized Real-Time Controllers	95
<i>David J. Musliner, Robert P. Goldman and Michael J. Pelican</i>	
 SYMPOSIUM: MOP2-4 (S)	
RANGE SENSING	
Active and Passive Range Sensing for Robotics	102
<i>Martial Hebert</i>	
Beyond Range Sensing: XYZ-RGB Digitizing and Modeling	111
<i>M. Rioux, F. Blais, A. B. Beraldin, G. Godin, P. Boulanger and M. Greenspan</i>	
Imaging Laser Scanners for 3-D Modeling and Surveying Applications	116
<i>D. Langer, M. Mettenleiter, F. Härtl and C. Fröhlich</i>	
Passive Night Vision Sensor Comparison for Unmanned Ground Vehicle Stereo Vision Navigation	122
<i>Ken Owens and Larry Matthies</i>	
Motion Estimation from Laser Ranging for Autonomous Comet Landing	132
<i>Andrew E. Johnson and A. Miguel San Martin</i>	
 SYMPOSIUM: MOP2-5 (S)	
PART FEEDING AND FIXTURING	
The Toppling Graph: Designing Pin Sequences for Part Feeding	139
<i>Tao Zhang, Gordon Smith, Robert-Paul Berretty, Mark Overmars and Ken Goldberg</i>	
A Reconfigurable Parts Feeder with an Array of Pins	147
<i>Sebastien J. Blind, Christopher C. McCullough, Srinivas Akella and Jean Ponce</i>	
Modeling and Throughput Prediction for Flexible Parts Feeders	154
<i>Michael S. Branicky, Greg C. Causey and Roger D. Quinn</i>	
An Implicit Time-Stepping Scheme for Rigid Body Dynamics with Coulomb Friction	162
<i>David Stewart and J. C. Trinkle</i>	
On Well-Defined Kinematic Metric Functions	170
<i>Qiao Lin and Joel W. Burdick</i>	
Positioning and Orienting a Class of Symmetric Parts Using a Combination of a Unit-Radial and a Constant Force Fields	178
<i>Florent Lamiraux and Lydia E. Kavraki</i>	

SYMPOSIUM: MOP2-6 (S)

PROTOTYPING DESIGN AND AUTOMATION

New Trends in Prototyping Design and Automation	184
<i>Kok-Meng Lee and Tarek M. Sobh</i>	
Prototyping Design and Automation of Micro/nano Manipulation System	192
<i>Toshio Fukuda and Fumihito Arai</i>	
Automating High-Throughput Fluid Sample Handling for Biotechnology and Chemistry	198
<i>D. R. Meldrum and S. E. Moody</i>	
Data Mining in Engineering Design: A Case Study	206
<i>A. Kusiak and T. L. Tseng</i>	
An Approach to Rapid Manufacturing with Custom Fixturing	212
<i>Mark Bloomenthal, Richard Riesefeld, Elaine Cohen and Russell Fish</i>	

SYMPOSIUM: TUA1-4 (S)

ROBOT CONTROL

Force Control of Robot Manipulators	220
<i>Tsuneo Yoshikawa</i>	
Passivity - Based Control	227
<i>Suguru Arimoto</i>	
Feedforward/Feedback Laws for the Control of Flexible Robots	233
<i>Alessandro De Luca</i>	
Experimental Identification of Robot Dynamics for Control	241
<i>J. Swevers, C. Ganseman, X. Chenut and J. C. Samin</i>	
Design of Steering Mechanism and Control of Nonholonomic Trailer Systems	247
<i>Yoshihiko Nakamura, Hideaki Ezaki, Yuegang Tan and Woojin Chung</i>	

SYMPOSIUM: TUA1-5 (S)

DEXTEROUS MANIPULATION

An Overview of Dexterous Manipulation	255
<i>Allison M. Okamura, Niels Smaby and Mark R. Cutkosky</i>	
The Planning and Control of Robot Dextrous Manipulation	263
<i>Li Han, Zexiang Li, Jeff C. Trinkle, Zhiqiang Qin and Shilong Jiang</i>	
Applying Principles of Robotics to Understand the Biomechanics, Neuromuscular Control and Clinical Rehabilitation of Human Digits	270
<i>Francisco J. Valero-Cuevas</i>	
A Discrete-Continuous Control Approach to Dextrous Manipulation	276
<i>Martin Buss and Thomas Schlegl</i>	
Rolling Contacts and Dexterous Manipulation	282
<i>Antonio Bicchi and Alessia Marigo</i>	

SYMPOSIUM: TUA1-6 (S)

ROBOT LEARNING

Real-Time Robot Learning with Locally Weighted Statistical Learning	288
<i>Stefan Schaal, Christopher G. Atkeson and Sethu Vijayakumar</i>	
Inverse Kinematics for Humanoid Robots	294
<i>Gaurav Tevatia and Stefan Schaal</i>	
Q2: Memory-Based Active Learning for Optimizing Noisy Continuous Functions	4095
<i>Andrew W. Moore, Jeff G. Schneider, Justin A. Boyan and Mary S. Lee</i>	
Robots Can Teach People How to Move Their Arm	300
<i>F. A. Mussa-Ivaldi and J. L. Patton</i>	
Towards Programming Tools for Robots that Integrate Probabilistic Computation and Learning	306
<i>Sebastian Thrun</i>	

SYMPOSIUM: TUA2-4 (S)

MOBILE ROBOTICS

Mobile Robot Navigation in Indoor Environments using Object and Character Recognition	313
<i>Masahiro Tomono and Shin'ich Yuta</i>	
A Real-Time Algorithm for Mobile Robot Mapping With Applications to Multi-Robot and 3D Mapping	321
<i>Sebastian Thrun, Wolfram Burgard and Dieter Fox</i>	
It's Time to Make Mobile Robots Programmable	329
<i>Yutaka J. Kanayama and C. Thomas Wu</i>	
Towards Dynamic Target Identification Using Optimal Design of Experiments	335
<i>Alberto Elfes, Marcel Bergerman and José Reginaldo H. Carvalho</i>	
Sensor Network Perception for Mobile Robotics	342
<i>Adam Hoover and Bent David Olsen</i>	

SYMPOSIUM: TUA2-5 (S)

GRASPING AND CONTACT

Robotic Grasping and Contact: A Review	348
<i>Antonio Bicchi and Vijay Kumar</i>	
Controllability of Single Input Rolling Manipulation	354
<i>Prasun Choudhury and Kevin M. Lynch</i>	
Stability Characterizations of Fixtured Rigid Bodies with Coulomb Friction	361
<i>J. S. Pang and J. C. Trinkle</i>	
Control Algorithm for Grasping and Manipulation by Multifingered Robot Hands Using Virtual Truss Model Representation of Internal Force	369
<i>Tsuneo Yoshikawa</i>	
Grasping Curved Objects through Rolling	377
<i>Yan-Bin Jia</i>	

SYMPOSIUM: TUA2-6 (S)
LEXIBLE AUTOMATION

Research Issues in Manufacturing Flexibility - An Invited Review Paper for ICRA 2000 Symposium on Flexibility <i>Daniel E. Whitney</i>	383
Scheduling and Coordination in Manufacturing Enterprise Automation <i>Haoxun Chen and Peter B. Luh</i>	389
A Life Cycle Engineering Approach to FMS Development <i>Pingtao Yan, MengChu Zhou and Reggie Caudill</i>	395
Object-Oriented Graphical Specification and Seamless Design Procedure for Manufacturing Cell Control Software Development <i>Satoshi Kanai, Takeshi Kishinami and Toyooki Tomura</i>	401
Supply Chain Engineering and Automation <i>N. Viswanadham</i>	408

SYMPOSIUM: TUP1-4 (S)
LOCOMOTION

Study on Quadruped Walking Robot in Tokyo Institute of Technology - Past, Present and Future <i>Shigeo Hirose and Keisuke Kato</i>	414
A Minimally Actuated Hopping Rover for Exploration of Celestial Bodies <i>Eric Hale, Nathan Schara, Joel Burdick and Paolo Fiorini</i>	420
Experiments in Carangiform Robotic Fish Locomotion <i>Richard Mason and Joel W. Burdick</i>	428
Adaptive Dynamic Walking of the Quadruped on Irregular Terrain — Autonomous Adaptation Using Neural System Model <i>Hiroshi Kimura and Yasuhiro Fukuoka</i>	436
Stable Running in a Quadruped Robot with Compliant Legs <i>Didier Papadopoulos and Martin Buehler</i>	444

SYMPOSIUM: TUP1-5 (S)
COOPERATIVE ROBOTS

Distributed Manipulation of Multiple Objects using Ropes <i>Bruce Donald, Larry Gariepy and Daniela Rus</i>	450
Distributed Robot Helpers Handling a Single Object in Cooperation with a Human <i>Yasuhisa Hirata and Kazuhiro Kosuge</i>	458
Knowledge Sharing and Cooperation of Autonomous Robots by Intelligent Data Carrier System <i>Daisuke Kurabayashi and Hajime Asama</i>	464
The Augmented Object Model: Cooperative Manipulation and Parallel Mechanism Dynamics <i>Kyong-Sok Chang, Robert Holmberg and Oussama Khatib</i>	470

Collaborative Multi-Robot Exploration	476
<i>Wolfram Burgard, Mark Moors, Dieter Fox, Reid Simmons and Sebastian Thrun</i>	
Experiments on Capturing a Floating Object by Two Flexible Manipulators	482
<i>Mitsuhiro Yamano, Atsushi Konno and Masaru Uchiyama</i>	
 SYMPOSIUM: TUP1-6 (S)	
MECHATRONICS	
Kinematics of Gel Robots made of Electro-Active Polymer PAMPS Gel	488
<i>Mihoko Otake, Masayuki Inaba and Hirochika Inoue</i>	
Toward Biomorphic Control Using Custom aVLSI CPG Chips	494
<i>M. Anthony Lewis, Ralph Etienne-Cummings, Avis H. Cohen and Mitra Hartmann</i>	
A Miniature Robotic System for Reconnaissance and Surveillance	501
<i>Dean F. Hougen, Saifallah Benjaafar, Jordan C. Bonney, John R. Budenske, Mark Dvorak, Maria Gini, Howard French, Donald G. Krantz, Perry Y. Li, Fred Malver, Brad Nelson, Nikolaos Papanikolopoulos, Paul E. Rybski, Sascha A. Stoeter, Richard Voyles and Kemal Berk Yesin</i>	
The Performance of a Deformable-Membrane Tactile Sensor: Basic Results on Geometrically-Defined Tasks	508
<i>Dimitris Hristu, Nicola Ferrier and Roger W. Brockett</i>	
PolyBot: A Modular Reconfigurable Robot	514
<i>Mark Yim, David G. Duff and Kimon D. Roufas</i>	
 SYMPOSIUM: WEA1-4 (S)	
MOTION PLANNING	
Path Planning Using Lazy PRM	521
<i>Robert Bohlin and Lydia E. Kavraki</i>	
Enhancing Randomized Motion Planners: Exploring with Haptic Hints	525
<i>O. Burchan Bayazit, Guang Song and Nancy M. Amato</i>	
Kinodynamic Motion Planning Amidst Moving Obstacles	537
<i>Robert Kindel, David Hsu, Jean-Claude Latombe and Stephen Rock</i>	
A Framework for Planning Feedback Motion Strategies Based on a Random Neighborhood Graph	544
<i>Libo Yang and Steven M. LaValle</i>	
Real-Time Replanning in High-Dimensional Configuration Spaces Using Sets of Homotopic Paths	550
<i>Oliver Brock and Oussama Khatib</i>	
 SYMPOSIUM: WEA1-5 (S)	
HUMAN AUGMENTATION AND ASSIST DEVICES	
Surface Waves for Active Transport of Bedridden Patients	556
<i>Joseph Spano and H. Harry Asada</i>	
Design and Control of Human Assisted Walking Robot	563
<i>Peter Neuhaus and H. Kazerooni</i>	

PAMM - A Robotic Aid to the Elderly for Mobility Assistance and Monitoring: A "Helping-Hand" for the Elderly ...	570
<i>Steven Dubowsky, Frank Genot, Sara Godding, Hisamitsu Kozono, Adam Skwersky, Haoyong Yu and Long Shen Yu</i>	
Detection of Human Mistakes and Misperception for Human Perceptive Augmentation: Behavior Monitoring Using Hybrid Hidden Markov Models	577
<i>Mitsuichi Hiratsuka and H. Harry Asada</i>	
Mobile Robot Helper	583
<i>Kazuhiro Kosuge, Manabu Sato and Norihide Kazamura</i>	
A Human-Robot Interface Using an Interactive Hand Pointer that Projects a Mark in the Real Work Space	589
<i>Shin Sato and Shigeyuki Sakane</i>	
 SYMPOSIUM: WEA1-6 (S)	
MEDICAL ROBOTICS	
Anisotropic Elasticity and Force Extrapolation to Improve Realism of Surgery Simulation	596
<i>Guillaume Picinbono, Jean-Christophe Lombardo, Hervé Delingette and Nicholas Ayache</i>	
Evaluating Control Modes for Constrained Robotic Surgery	603
<i>Fuji Lai and Robert D. Howe</i>	
Preliminary Experiments in Cooperative Human/Robot Force Control for Robot Assisted Microsurgical Manipulation	610
<i>Rajesh Kumar, Peter Berkelman, Puneet Gupta, Aaron Barnes, Patrick S. Jensen, Louis L. Whitcomb and Russell H. Taylor</i>	
The Intuitive™ Telesurgery System: Overview and Application	618
<i>Gary S. Guthart and J. Kenneth Salisbury, Jr.</i>	
Neurobot: A Special-Purpose Robot for Neurosurgery	4103
<i>B. Davies, S. Starkie, S. J. Harris, E. Agterhuis, V. Paul and L. M. Auer</i>	
 SYMPOSIUM: WEP1-4 (S)	
REAL-TIME VISUAL SERVOING AND TRACKING	
Real-Time Vision, Tracking and Control	622
<i>Peter I. Corke and Seth A. Hutchinson</i>	
2 1/2 D Visual Servoing: A Possible Solution to Improve Image-Based and Position-Based Visual Servoings	630
<i>François Chaumette and Ezio Malis</i>	
On Specifying and Performing Visual Tasks with Qualitative Object Models	636
<i>Gregory D. Hager and Zachary Dodds</i>	
Dynamics and System Performance of Visual Servoing	644
<i>Markus Vincze</i>	
1ms Column Parallel Vision System and It's Application of High Speed Target Tracking	650
<i>Y. Nakabo, M. Ishikawa, H. Toyoda and S. Mizuno</i>	

SYMPOSIUM: WEP1-5 (S)

DYNAMIC SIMULATION OF HUMANOID MOTION

Simulating Leaping, Tumbling, Landing, and Balancing Humans	656
<i>W. L. Wooten and J. K. Hodgins</i>	
Force-Based Motion Editing for Locomotion Tasks	663
<i>Nancy S. Pollard and Fareed Behmaram-Mosavat</i>	
Editing Dynamic Properties of Captured Human Motion	670
<i>Zoran Popović</i>	
Dynamic Simulation of Human Movement Using Large-Scale Models of the Body	676
<i>Marcus G. Pandy and Frank C. Anderson</i>	
Towards Agile Animated Characters	682
<i>Michiel van de Panne, Joe Laszlo, Pedro Huang and Petros Faloutsos</i>	
Dynamics Filter — Concept and Implementation of On-Line Motion Generator for Human Figures	688
<i>Katsu Yamane and Yoshihiko Nakamura</i>	

SYMPOSIUM: WEP1-6 (S)

INDUSTRIAL ROBOTS

Product and Technology Trends for Industrial Robots	696
<i>Hadi A. Akeel and Steve W. Holland</i>	
Robot Mechanisms	701
<i>Brian Carlisle</i>	
Underwater Robotics: Out of the Research Laboratory and Into the Field	709
<i>Louis L. Whitcomb</i>	
The PC and its Influence on Robot Controllers	717
<i>Gary J. Rutledge</i>	

SYMPOSIUM: WEP2-4 (S)

CONSTRAINED MOTION PLANNING AND CONTROL

Motion Planning of Objects in Contact by the Silhouette Algorithm	722
<i>Hirohisa Hirukawa and Yves Papegay</i>	
Hybrid Dynamic Control and Adaptation of Constrained Manipulation Systems	730
<i>Brenan J. McCarragher</i>	
A Unified Approach to Modeling and Realization of Constraint Robot Motion using Singularly Perturbed Sliding Manifolds	736
<i>H. Harry Asada, Bei Gu and Brandon W. Gordon</i>	
Generating Polyhedral Convex Cones from Contact Graphs for the Identification of Assembly Process States	744
<i>H. Mosemann, T. Bierwirth, F. Wahl and S. A. Stoeter</i>	
A Divide-and-Merge Approach to Automatic Generation of Contact States and Planning of Contact Motion	750
<i>Jing Xiao and Xuerong Ji</i>	

SYMPOSIUM: WEP2-5 (S)

HAPTICS

Some Current Issues in Haptics Research	757
<i>John M. Hollerbach</i>	
Isotropy and Actuator Optimization in Haptic Interface Design	763
<i>S. E. Salcudean and L. Stocco</i>	
Stable Haptic Interaction Using the Excalibur Force Display	770
<i>Richard J. Adams, Daniel Klowden and Blake Hannaford</i>	
Human Tactile Spatial Sensitivity for Tactile Feedback	776
<i>G. Moy, U. Singh, E. Tan and R. S. Fearing</i>	
Designing with Haptic Feedback	783
<i>Karon E. MacLean</i>	
Haptic Interface Control — Design Issues and Experiments with a Planar Device	789
<i>Mohammad R. Sirouspour, S. P. DiMaio, S. E. Salcudean, P. Abolmaesumi and C. Jones</i>	

SYMPOSIUM: WEP2-6 (S)

ENTERTAINMENT

Robotics in Edutainment	795
<i>Minoru Asada, Raffaello D'Andrea, Andreas Birk, Hiroaki Kitano and Manuela Veloso</i>	
Digital Creatures for Future Entertainment Robotics	801
<i>Masahiro Fujita</i>	
RoboCup Jr.: RoboCup for Edutainment	807
<i>Hiroaki Kitano, Sho'ji Suzuki and Junichi Akita</i>	
RoboCup Jr. with LEGO Mindstorms	813
<i>Henrik Hautop Lund and Luigi Pagliarini</i>	
The Outline of the International Robot Games Festival	820
<i>E. Nakano, M. Asada, S. Tadokoro, K. Osuka, K. Nagai, Y. Masutani and H. Kitano</i>	
Robot Improv: Using Drama To Create Believable Agents	4002
<i>Allison Bruce, Jonathan Knight, Samuel Listopad, Brian Magerko, and Illah R. Nourbakhsh</i>	

SYMPOSIUM: THA1-4 (S)

ROBOT DYNAMICS

Robot Dynamics: Equations and Algorithms	826
<i>Roy Featherstone and David Orin</i>	
Practical Models for Practical Flexible Arms	835
<i>Wayne Book and Klaus Oberfell</i>	
Computational Robot Dynamics Using Spatial Operators	843
<i>Abhi Jain and Guillermo Rodriguez</i>	

Operational Space Dynamics: Efficient Algorithms for Modeling and Control of Branching Mechanisms	850
<i>Kyong-Sok Chang and Oussama Khatib</i>	
Forward Dynamics Algorithms for Multibody Chains and Contact	857
<i>Dinesh K. Pai, Uri M. Ascher and Paul G. Kry</i>	
 SYMPOSIUM: THA1-5 (S)	
VISUAL MODELING AND RECONSTRUCTION	
Surface Simplex Meshes for 3D Medical Image Segmentation	864
<i>J. Montagnat, H. Delingette, N. Scapellato and N. Ayache</i>	
Constructing Geometric Object Models from Images	871
<i>Jean Ponce, Yakup Genc and Steve Sullivan</i>	
Terrain Reconstruction for Ground and Underwater Robots	879
<i>R. Mandelbaum, G. Salgiani, H. Sawhney and M. Hansen</i>	
Self-Calibration Using the Linear Projective Reconstruction	885
<i>Jong-Eun Ha, Jin-Young Yang, Kuk-Jin Yoon and In-So Kweon</i>	
3-D Map Reconstruction from Range Data	891
<i>Daniel Huber, Owen Carmichael and Martial Hebert</i>	
 SYMPOSIUM: THA1-6 (S)	
HUMAN FRONTIER ENVIRONMENTS	
Advances in Orbital Robotics	898
<i>G. Hirzinger, B. Brunner, R. Lampariello, K. Landzettel, J. Schott and B.-M. Steinmetz</i>	
Ground Mobility Systems for Planetary Exploration	908
<i>Paolo Fiorini</i>	
Experiences and Lessons Learned from the ETS-VII Robot Satellite	914
<i>Mitsushige Oda</i>	
Behavior-Based Control for Autonomous Underwater Exploration	920
<i>Julio Rosenblatt, Stefan Williams and Hugh Durrant-Whyte</i>	
Enhanced Mars Rover Navigation Techniques	926
<i>Richard Volpe, Tara Estlin, Sharon Laubach, Clark Olson and J. (Bob) Balaram</i>	
Underwater Robotics	932
<i>J. Yuh</i>	
 SYMPOSIUM: THA2-5 (S)	
MEMS	
MEMS and Robotics: Promises and Problems	938
<i>Peter Will</i>	