Antonio Bicchi, Henrik I. Christensen and Domenico Prattichizzo (Eds)

Control Problems in Robotics

Springer

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Contents

Path Optimization for Nonholonomic Systems: Application to Reactive Obstacle Avoidance and Path Planning 1
Florent Lamiraux, David Bonnafous, Carl Van Geem
1 Introduction 1
2 Nonholonomic Systems and Path Deformation 3
3 Application to the Mobile Robot Hilare Towing a Trailer 8
4 Application to Path Planning for Trucks and Trailers 12
5 Conclusion and Future Work 16

From Dynamic Programming to RRTs: Algorithmic Design of Feasible Trajectories 19
Steven M. LaValle
1 Introduction 19
2 Generic Problem Formulation 20
3 Dynamic Programming 22
4 Rapidly-Exploring Random Trees 27
5 Research Challenges 31

Control of Nonprehensile Manipulation 39
Kevin M. Lynch, Todd D. Murphey
1 Introduction 39
2 Definitions 41
3 Dynamic Underactuated Nonprehensile Manipulation 44
4 Distributed Manipulation and Open Problems 50

Motion Planning and Control Problems for Underactuated Robots 59
Sonia Martínez, Jorge Cortés, Francesco Bullo
1 Motivating Problems from a Variety of Robotic Applications 59
2 Mathematical Unifying Approach to the Modeling of Robotic Systems 62
3 Existing Results on Planning for Underactuated Systems 65
4 Open Problems and Possible Approaches 69

Motion Description Languages for Multi-Modal Control in Robotics 75
Magnus Egerstedt
1 Introduction 75
2 Motion Description Languages 76
3 Description Lengths 80
4 A Unified Approach to Control and Hardware Design 84
5 Preliminary Results 86

6 Further Issues 87

Polynomial Design of Dynamics-based Information Processing System 91
Masafumi Okada, Yoshihiko Nakamura
1 Introduction 91
2 Dynamics and Whole Body Motion 92
3 Motion Reduction and Symbolization 93
4 Design of Dynamics-Based Information Processing System 94
5 Generation of the Whole Body Motion 100
6 Conclusion 102

Actuation Methods For Human-Centered Robotics and Associated Control Challenges 105
Michael Zinn, Oussama Khatib, Bernard Roth, J. Kenneth Salisbury
1 Introduction 105
2 New Actuation Approaches 108
3 Conclusion 119

Control of a Flexible Manipulator with Noncollocated Feedback: Time Domain Passivity Approach 121
Jee-Hwan Ryu, Dong-Soo Kwon, Blake Hannaford
1 Introduction 121
2 Review of Time Domain Passivity Approach 122
3 Implementation Issues 127
4 Simulation Examples 129
5 Discussion 130

Cartesian Compliant Control Strategies for Light-Weight, Flexible Joint Robots 135
Alin Albu-Schäffer, Gerd Hirzinger
1 Introduction 135
2 Cartesian Compliant Control 136
3 Control of the flexible joint robot 140
4 Experiments 147
5 Discussion 149
6 Conclusion 149

Toward the Control of Self-Assembling Systems 153
Eric Klavins
1 Introduction 153
2 Related Work 155
3 Modeling 156
4 Discussion 162
5 Conclusion 166

Towards Abstraction and Control for Large Groups of Robots ... 169
Calin Belta, Vijay Kumar
1 Introduction ... 169
2 Definitions and Problem Formulation ... 171
3 Mean and Covariance Control for Fully Actuated Planar Robots ... 173
4 Mean and Variance Control for Fully Actuated Planar Robots ... 179
5 Conclusion ... 181

Omnidirectional Sensing for Robot Control ... 183
Kostas Daniilidis, Christopher Geyer, Volkan Isler, Ameesh Makadia
1 Introduction ... 183
2 A Unifying Projection Model ... 184
3 The Signal Question ... 185
4 The Geometry Question ... 187
5 The Planning Question ... 191
6 Future Work ... 196

A Passivity Approach to Vision-based Dynamic Control of Robots with Nonlinear Observer ... 199
Hiroyuki Kawai, Shintaro Izoe, Masayuki Fujita
1 Introduction ... 199
2 Relative Rigid Body Motion ... 201
3 Visual Feedback System ... 202
4 Vision-based Robot Control ... 207
5 Conclusions ... 212

Visual Servoing along Epipoles ... 215
Jacopo Piazzi, Domenico Prattichizzo, Antonio Vicino
1 Introduction ... 215
2 Notation ... 216
3 Visual Servoing Algorithm ... 218
4 Experiments ... 226
5 Conclusions and Open Problems ... 228

Toward Geometric Visual Servoing ... 233
Noah John Cowan, Dong Eui Chang
1 Introduction ... 233
2 Six DOF Diffeomorphism to Image-space ... 235
3 Image Jacobian ... 240
4 Controller ... 242
5 Conclusion ... 245

Vision-Based Online Trajectory Generation and Its Application to Catching 249
Akio Namiki, Masatoshi Ishikawa
1 Introduction 249
2 Related Works 250
3 Vision-Based Online Trajectory Generator 251
4 Experiment 257
5 Conclusion 259

Stability Analysis of Invariant Visual Servoing and Robustness to Parametric Uncertainties 265
Ezio Malis
1 Introduction 265
2 Modeling 267
3 Vision-based control 269
4 Stability Analysis 270
5 Robustness to Parametric Uncertainties 272
6 Open problems 273
7 Experimental Results 274
8 Conclusion 277

Foreword

The field of robotics continues to flourish and develop. In common with general scientific investigation, new ideas and implementations emerge quite spontaneously and these are discussed, used, discarded or subsumed at conferences, in the reference journals, as well as through the Internet. After a little more maturity has been acquired by the new concepts, then archival publication as a scientific or engineering monograph may occur.

The goal of the Springer Tracts in Advanced Robotics is to publish new developments and advances in the fields of robotics research – rapidly and informally but with a high quality. It is hoped that prospective authors will welcome the opportunity to publish a structured presentation of some of the emerging robotics methodologies and technologies.

The edited volume by Antonio Bicchi, Henrik Christensen and Domenico Prattichizzo is the outcome of the second edition of a workshop jointly sponsored by the IEEE Control Systems Society and the IEEE Robotics and Automation Society. Noticeably, the previous volume was published in the Springer Lecture Notes on Control and Information Sciences.

The authors are recognised as leading scholars internationally. A number of challenging control problems on the forefront of today's research in robotics and automation are covered, with special emphasis on vision, sensory-feedback control, human-centered robotics, manipulation, planning, flexible and cooperative robots, assembly systems.

Besides the theoretical advancement, most contributions survey the state-of-the-art in the field, report a number of practical applications to real systems, and discuss possible future developments. A fine addition to the series!

Bruno Siciliano
STAR Editor

Preface

This book aims at reporting on some of the most exciting problems of control theoretic nature raised by robotics applications. It is a long-time tradition of the two communities, represented within IEEE by the Control Systems Society (CSS) and by the Robotics and Automation Society (RAS) respectively, to lead the effort to identify innovative applications and related technology demands from our society, as well as in providing the enabling technical solutions.

To further such tradition of cross-disciplinary fertilization and discussion, IEEE CSS and RAS joined with EURON (the European Union Network of Excellence in Robotics) and RSJ (the Robotics Society of Japan) in organizing the *Second International Workshop on Control Problems in Robotics and Automation*, held in Las Vegas, Nevada, on December 14, 2002.

Chapters in this book are edited versions of papers that were selected for presentation at the Workshop. An International Steering Committee, composed of renowned scientists such as H. Arai, J. Bailleul, R. Bajcsy, J. Burdick, R. Chatila, E. Feron, G. Hirzinger, J. Hollerbach, D. Koditscheck, K. Kosuge, V. Kumar, Y. Nakamura, F. Park, S. Sastry, B. Siciliano, M. Spong, and T. Yoshikawa, helped in choosing promising areas and researchers to be invited to participate. Innovative and problematic contributions have been promoted, as well as young and energetic investigators. Unsolicited submissions were also encouraged. All contributions have gone through a thorough review process before reaching their final form.

The organization of the material in the book is as follows. A first group of chapters is concerned with trajectory generation and optimization for classes of complex mechanical systems as they are encountered in advanced robotics applications. These include kinematic and dynamic nonholonomic systems, as e.g. is the case with robot vehicles and under-actuated manipulators, respectively. Two contributions on kinematic nonholonomic systems are *Path optimization for nonholonomic systems: application to reactive obstacle avoidance and path planning* by F. Lamiraux, D. Bonnafous, and C. Van Geem, and *From dynamic programming to RRTs: algorithmic design of feasible trajectories*, by S. La Valle. Two chapters, *Control of nonprehensile manipulation*, by K. M. Lynch, T. D. Murphey, and *Motion planning and control problems for underactuated robots* by S. Martinez, J. Cortes, and F. Bullo, address planning and control for underactuated systems. The chapter *Motion description languages for multi-modal control in robotics*, by M. Egerstedt, addresses some more general questions about how a general language for describing motions of robotic systems could be conceived

A second group of contributions deals with robotic systems designed to interact directly with human operators. Humanoids and human-friendly robots,

about which recently there is much talking even in the popular press, are topics of great applicative potential that involve extremely challenging control problems. The chapter *Polynomial design of dynamics-based information processing system*, by M. Okada and Y. Nakamura, describes one of the problems in designing the dynamic motion of such a complex system as a humanoid, where the number of degrees-of-freedom renders traditional approaches simply unfeasible. Robots interacting with human operators in a safe and dependable way are often designed (sometimes with a biomechanical inspiration) with a lightweight and flexible arm structure. Three chapters in this book deal with how such arms can be designed and controlled: these are *Control challenges of low impedance actuators for human-friendly robotics*, by M. Zinn, O. Khatib, B. Roth, J. K. Salisbury; *Control of a Flexible Manipulator with Noncollocated Feedback: Time Domain Passivity Approach*, by J.-H. Ryu, D.-S. Kwon and B. Hannaford; and *Cartesian compliant control strategies for light-weight, flexible joint robots*, by A. Albu-Schaeffer and G. Hirzinger.

Another prominent avenue of research being currently explored in robotics is the study of "group robotics", i.e. systems formed by many autonomous or semi-autonomous systems cooperating in certain tasks. The chapter *Toward the control of self assembling systems with autonomous mesoscale parts* by E. Klavins explores the possibilities offered by systems that can assembly themselves in more complex structures, while *Towards abstraction and control for large groups of robots* by C. Belta and V. Kumar introduces a formalization of group behaviours and their control.

A relatively large number of chapters in this book is devoted to the application of artificial vision to robotics. This is so because the topic has attracted, in the last few years, a widespread attention from both practitioners and scholars, due to its potentials (think e.g. of replacing costly localization apparatuses in an automated factory with cheap onboard cameras) and to its technical challenges. Chapters contributed to the field include *Omnidirectional sensing for robot control*, by K. Daniilidis, C. Geyer, V. Isler and A. Makadia; *A passivity approach to vision-based dynamic control of robots with nonlinear observer*, by H. Kawai, S. Izoe and M. Fujita; *Visual servoing along epipoles*, by J. Piazzi, D. Prattichizzo, and A. Vicino; *Toward geometric visual servoing*, by N. J. Cowan and D. E. Chang; *Vision based online trajectory generation and its application to catching*, by A. Namiki and M. Ishikawa; and *Stability analysis of invariant visual servoing and robustness to parametric uncertainties*, by E. Malis.

October, 2002

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