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Vincent Duindam and Stefano Stramigioli

Modeling and Control for Efficient Bipedal Walking Robots

A Port-Based Approach

Springer

Professor Bruno Siciliano, Dipartimento di Informatica e Sistemistica, Università di Napoli Federico II, Via Claudio 21, 80125 Napoli, Italy, E-mail: siciliano@unina.it

Professor Oussama Khatib, Robotics Laboratory, Department of Computer Science, Stanford University, Stanford, CA 94305-9010, USA, E-mail: khatib@cs.stanford.edu

Professor Frans Groen, Department of Computer Science, Universiteit van Amsterdam, Kruislaan 403, 1098 SJ Amsterdam, The Netherlands, E-mail: groen@science.uva.nl

Authors

Vincent Duindam
University of California at Berkeley
253 Cory Hall #1770
Berkeley, CA 94720
USA
E-Mail: v.duindam@ieee.org

Stefano Stramigioli
Impact Institute
University of Twente
P.O. Box 217
7500 AE Enschede
Netherlands
E-Mail: s.stramigioli@ieee.org

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Foreword

By the dawn of the new millennium, robotics has undergone a major transformation in scope and dimensions. This expansion has been brought about by the maturity of the field and the advances in its related technologies. From a largely dominant industrial focus, robotics has been rapidly expanding into the challenges of the human world. The new generation of robots is expected to safely and dependably co-habitat with humans in homes, workplaces, and communities, providing support in services, entertainment, education, healthcare, manufacturing, and assistance.

Beyond its impact on physical robots, the body of knowledge robotics has produced is revealing a much wider range of applications reaching across diverse research areas and scientific disciplines, such as: biomechanics, haptics, neurosciences, virtual simulation, animation, surgery, and sensor networks among others. In return, the challenges of the new emerging areas are proving an abundant source of stimulation and insights for the field of robotics. It is indeed at the intersection of disciplines that the most striking advances happen.

The goal of the series of Springer Tracts in Advanced Robotics (STAR) is to bring, in a timely fashion, the latest advances and developments in robotics on the basis of their significance and quality. It is our hope that the wider dissemination of research developments will stimulate more exchanges and collaborations among the research community and contribute to further advancement of this rapidly growing field.

The monograph written by Vincent Duindam and Stefano Stramigioli is the second in the series devoted to biped robots. The challenge of this work is to demonstrate how advanced mathematical tools of differential geometry, port Hamiltonian systems and bond graphs can be successfully applied for robust and stable control of walking robots. The approach is substantiated by several experiments on different set-ups, revealing a potential to fill the gap between the adoption of passive dynamic walkers and the resort to active position-controlled walking robots.

The monograph is expanded from the doctoral dissertation of the first author, which was a finalist for the "Technology Transfer" section of the Seventh Edition of the EURON Georges Giralt PhD Award. A very fine addition to STAR!

Naples, Italy
August 2008

Bruno Siciliano
STAR Editor

Preface

Walking robots are complex machines with many degrees of freedom. Designing efficient controllers for such robots can be a daunting task, and the differential equations by themselves usually do not help much when trying to understand the dynamics. Still, research on passive dynamic walking robots has shown that it is possible to make robotic mechanisms walk very naturally and efficiently without using any control! The gap between theoretically well-understood position-controlled walking robots and experimentally-designed uncontrolled passive-dynamic walkers is nevertheless large, and extending a passive-dynamic walker to be more robust and versatile is non-trivial.

The purpose of this work is to present a set of mathematical tools that can simplify studying robotic walking motions and designing energy-efficient controllers. We extend classical dynamic modeling methods and view robots and controllers as energy-exchanging physical systems, which forms the basis of the so-called port-based approach. We show how such methods can be used to analyze walking mechanisms, find efficient walking trajectories, and design controllers that increase robustness and stability with minimal energy cost. We use extensive examples and illustrations with the objective to make the mathematics intuitive and accessible to everyone with an engineering background: we believe advanced math can be beautiful without being difficult!

This book is based on the first author's dissertation work at the University of Twente, as part of the EU-sponsored project GeoPlex. We would like to thank all members of the GeoPlex consortium for their direct and indirect contributions to the results in this book and for the many enlightening discussions we had about the topic. We also thank our colleagues of the Control Engineering Lab at the University of Twente for the extensive collaboration

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Vincent Duindam
Stefano Stramigioli

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