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Cartesian Impedance Control of Redundant and Flexible-Joint Robots

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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 Christian Ott is devoted to the classical research topic of impedance control which has recently found new interest after the progress in the mechanical design of lightweight robotic systems with improved actuation and sensing principles. The contents expand the author's doctoral dissertation and are focused on two key issues, namely joint flexibility and kinematic redundancy. A number of effective controllers are developed in theory, based on consolidated approaches such as singular perturbation and passivity, and are tested in extensive experiments on the DLR humanoid manipulator 'Justin', one of the most advanced robotic systems available up to date from a technology and mechatronics standpoint. No doubt, a very fine addition to the STAR series!

Naples, Italy,
April 2008

Bruno Siciliano
STAR Editor

Preface

This monograph is based on my PhD thesis, which was written at the Institute of Robotics and Mechatronics at the German Aerospace Center (DLR e.V.), and which was defended at Saarland University in November 2005. Its main topic is the Cartesian impedance control problem. While the basic concept of impedance control is well known since several years, its implementation in a wide range of applications nowadays comes into focus of robotics research again due to recent progress in the mechanical design of robotic systems with new and improved actuation principles. Moreover, the availability of more and more complex robot mechanisms allows us also to refine the control theory by considering more detailed and thus more precise models. In the present work, in particular the effect of joint elasticity on the design of impedance controllers is analyzed in detail. The consideration of joint elasticity is particularly relevant for lightweight robots in service robotics scenarios as well as for industrial robots when high accuracy is required also for very fast movements. Another topic treated in this work is the extension to redundant systems in which the robot has more degrees of freedom than necessary to fulfill a given task. This is especially important for more complex robotic systems like robots with multiple arms and hands.

The book also contains an applications chapter with several experiments in which the control methods have been applied. This includes also some more recent experiments with DLR's upper-body manipulator "Justin", which goes beyond what was originally included in the PhD thesis.

During the the work on the thesis a lot of people gave me support and advice in many different ways. First of all I want to thank Prof. Gerd Hirzinger, Head of the Institute of Robotics and Mechatronics, for he gave me the possibility to conduct research in the exciting field of robot control.

I am very grateful to Prof. Andreas Kugi, my Ph.D. supervisor from the Chair of System Theory and Automatic Control at Saarland University, for support and invaluable advice. Whenever I visited his lab he spared much time for discussing my work.

I would also like to express my gratitude to the colleagues at DLR. In particular I want to thank Dr. Alin Albu-Schäffer for the enjoyable cooperation and the

stimulating conversations over the years. Moreover, I would also like to thank Dr. Alin Albu-Schäffer, Dr. Udo Frese, and Dr. Tobias Ortmaier for proofreading the thesis on which this book is based on.

During my Ph.D. research I had the opportunity to spend a period of three month at the University of Twente, The Netherlands, where I visited the groups of Prof. Stefano Stramigioli and Prof. Arjan van der Schaft. This visit significantly influenced my understandings of passivity based control and its use for redundant and flexible robots.

Finally, I would like to thank Prof. Bruno Siciliano and Dr. Thomas Ditzinger for their patience in waiting for the final modifications of the book.

Tokyo, April 2008 Christian Ott

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