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Dezhen Song

Sharing a Vision

Systems and Algorithms for Collaboratively-Teleoperated Robotic Cameras

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To my parents and to Ye

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 Dezhen Song is focused on a robotic camera simultaneously controlled by multiple online users via the Internet. A challenging match between the collaboratively tele-operated robotic cameras and the needs from nature environment observation is sought, which greatly extends the domain of online robots in both application and technology development directions, including building construction site monitoring, public space surveillance, and distance education. New solutions are proposed which demonstrate the enormous potential of Internet-based infrastructures for immediate success in the market.

This book is the outcome of the author's doctoral work and research conducted in his early stage of academic career. Effectively organized in three parts after an introduction to the subject matter, the volume constitutes a very fine addition to the STAR series!

Naples, Italy
June 2008

Bruno Siciliano
STAR Editor

Preface

The work presented in this book summarizes my thesis work and the research conducted early in my academic career (2000 - 2007 AD).

In 1996, I was fascinated by the tremendous potential of the Internet and co-found an Internet-based video surveillance company. The simple integration of the communication infrastructure and an array of visual sensors was an immediate success in the market. While my partners were drawn deeper into the excitement of entrepreneurship, I actually became more and more interested in integrating human users with sensors via the Internet. I realized that Internet is not only a vast network of wires and routers but also a vast social network which never existed before. A deep understanding of the topic would require a serious academic approach, which inspired me to pursuit an academic career.

In 2000, I was fortunate enough to be admitted into the graduate program of University of California, Berkeley. What was more exciting was being able to work with Prof. Ken Goldberg, who pioneers the research in the Internet-based Tele-operation. Ken's research interest at the time was to investigate how to allow a group of online users to collaboratively control a single robot, which is apparently a great fit to my personal interests. Ken's group has attempted strategies such as averaging. This method has proved to be viable and effective in noise reduction when controlling a 4 degrees-of-freedom (DOF) industry arm. However, the simple aggregation strategy does not work when a robotic camera replaces the industry robot. This quickly becomes my Ph.D. thesis topic. The rest of time in Berkeley becomes the most enjoyable time in my life.

In 2004, I was again fortunate that the Computer Science Department of Texas A&M University offered me an assistant professor position. I was excited with the opportunity to continue my research and to work with well-known robotics researchers such as Prof. Richard Volz and Prof. Nancy Amato. The support from the department and the university allows me to quickly establish my own research group. The taste of academic freedom is just unbelievable. As a young researcher, I am hungry and eager to prove myself. We extend the research from laboratory settings to challenges in real world applications such as building

construction site monitoring, public space surveillance, distance education, and nature environment observation.

Finding the match between the collaboratively tele-operated robotic cameras and the needs from nature environment observation was the most exciting moment in past few years. For many years, the researchers in the online robots field struggle to find new applications other than health care, education, and surveillance. The new match greatly extends the domain of online robots in both application and technology development directions. On the one hand, we provide new solutions to address the primary challenges in nature environment observation. On the other hand, the challenging nature environment presents us a lot of new research problems to explore. This book summarizes our recent development and hopefully provides insights for researchers in similar domains.

Acknowledgement

There is absolutely no way that I can accomplish this work my all by myself. This is a joint adventure with my collaborators in past seven years.

First of all, I would like to thank for Prof. Ken Goldberg. Ken is the best thesis advisor and the greatest mentor. Ken's inspirational thinking, unique scientific/artistic styles in technical writing and presentation, and tremendous support essentially convert me from a naive graduate student to an independent academic researcher.

I also would like to thank my thesis committee members: Prof. A. Frank van der Stappen, Prof. Ilan Adler, Prof. Satish Rao, and Prof. Andrew Lim for their great inputs and help in improving my thesis. I would like to specially thank for Frank. Frank is not just my thesis committee member but another thesis advisor that I was fortunate to work with. With a keen feeling on the geometric aspect of the collaborative camera control problem, Frank's inputs guide me to investigate the collaborative control problem from this new perspective, which yields fruitful results.

I am grateful for Prof. Richard Volz and Prof. Nancy Amato for their help early in my career. They are great mentors for me and always remind me of things that a new faculty would tend to forget. I appreciate the great opportunity and the great support provided by Prof. Valerie Taylor and the Department of Computer Science of Texas A&M University. I am grateful for Prof. Ricardo Gutierrez-Osuna, Prof. Wei Zhao, and colleagues in the department for their help and inputs.

With projects stretch for over seven years, I am sure that I may forget to include some important names. I want to apologize for this ahead of time. For the tele-actor project, I would like to thank E. Paulos and D. Pescovitz for valuable inputs on initial experiments; J. Donath and her students at MIT Media Lab; E. Paulos, C. Myers, and M. Fogarty for helmet design; the other students who have participated in the project: A. Levandoski, J. McGonigal, W. Zheng, A. Ho, M. McKelvin, I. Song, B. Chen, R. Aust, M. Metz, M. Faldu, V. Colburn, Y. Khor, J. Himmelstein, J. Wang, J. Shih, K. Gopal Gopalakrishnan, F. Hsu,

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College Station, TX, USA *Dezhen Song*
June 2008

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