AN ADVANCED TRAJECTORY PLANNER FOR INDUSTRIAL ROBOT MANIPULATORS

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dissertation submitted in partial fulfillment of the requirements
for the Degree of Doctor of Philosophy in Robotics and Systems Control
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March, 2003

Abstract

This thesis focuses on trajectory planning for industrial robot manipulators. It describes the existing problem of trajectory planning and proposes an appropriate solution. The proposed solution has been devised, implemented and verified for effective functionality. Trajectory planning in this context is the process of planning time-based joint position trajectories for a desired end-effector motion. It needs to consider all relevant constraints of the manipulator and given task specifications, because the final end-effector performance totally depends on the way the joint trajectories are planned. However, most trajectory planners in industrial robotics, even today, have adapted the technique of direct sampling of the desired end-effector motion, and transform such Cartesian positions to joint space using inverse kinematics. Then, the planned joint trajectories are simulated to check if they are realizable within the constraints. It is also inspected if the given task specifications are fulfilled sufficiently. Planned end-effector trajectory is iteratively adjusted by trial-and-error, until an optimum trajectory is obtained. This process has many demerits and it is therefore necessary to develop an appropriate trajectory planning algorithm which has provisions to consider constraints and task specifications in planning end-effector trajectories. It should also be generally applicable to industrial manipulators.

Through constant collaboration with Yaskawa Robotics Inc., the major considerations of trajectory planning were identified as being : 1. trajectory allowance, 2. sharp corners, 3. joint acceleration limit, 4. assigned end-effector velocity, 5. jerk reduction, and 6. delay dynamics. They were considered one-by-one, and techniques were developed to incorporate them into a single trajectory planner. Usually, desired end-effector trajectory is not the optimal trajectory. Therefore, the trajectory planner plans a realizable trajectory with the mentioned considerations above. Realizable trajectory is the optimal trajectory within the given trajectory allowance. At sharp corners, a circular arc is introduced within the trajectory allowance. Joint acceleration limit refers to the power amplifier current rating of the servo controller, and assigned end-effector velocity is the speed specification. End-effector trajectory can be planned using maximum joint acceleration as long as the end-effector remains below the assigned velocity. However, as the end-effector reaches assigned velocity, joint accelerations should be reduced and the speed should be uniformly maintained. Jerk can be reduced by fitting a spline approximation to the planned joint trajectories. Delay dynamics can be compensated by way of pole placement techniques and optimizing the pole by considering servo control input. The proposed trajectory planner was devised and implemented to control an industrial robot manipulator (Performer MK3s) so that a significant improvement of end-effector performance could be demonstrated. The same trajectory planner was rearranged into an autonomous module and incorporated with real-time control. This new implementation was proposed and implemented for supervisory controlled telerobotics applications. It was also applied for welfare robotics applications.

Proposed trajectory planner is an off-line process, and it does not require hardware alterations. Thus, it could be conveniently implemented with existing robot manipulator systems.

Approval

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CERTIFICATE OF APPROVAL

Ph.D. Dissertation

This is to certify that the Ph.D. Dissertation of

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Dedication

To my loving parents and great teachers

For bringing me up this far...

Acknowledgements

Professor Masatoshi Nakamura, my PhD supervisor is heartfully acknowledged for his invaluable guidance in promoting my doctoral studies at the Advanced Systems Control Engineering Laboratory, in Saga University. He extended his guidance far beyond research toward important aspects of life. Professor Nobuhiro Kyura, my research collaborator from Yaskawa Robotics Incorporation is warmly acknowledged for his great supervision of my research. It has been an excellent collaboration, which eventually lead to research so fruitful. Sincere gratitude is also for Professor Katsunori Shida, Professor Keigo Watanabe, and Associate Professor Satoru Goto for being co-supervisors of my doctoral research. Special regards are for Dr. Naruto Egashira for his kind corporation in telerobotic system developments.

Rev. Mervyn Fernando, Director of the Institute of Integral Education, Sri Lanka is also acknowlwdged for being a great teacher in my life. Acknowledgements are also to Sir Arthur C. Clarke, Chancellor, International Space University, and Rev. Prof. George V. Coyne, Director, Vatican Obsrvatory, for having a great guidance in my academic career.

Sincere gratitudes are extended to Lecturer Dr. Takenao Sugi, Technical officer Mr. Kazunari Nagafuchi, and Secretary Mrs. Minako Egashira for their great friendship and corporation. Heartfelt thanks are also for the postdoc fellow Dr. Daisuke Kushida and all colleagues in the Department of Advanced Systems Control Engineering, for their friendship, company, and helping hands, particularly at times of language related clerical works.

Dr. Nishantha Nanayakkara at the University of Moratuwa, Sri Lanka is warmely achnowledged for his helping me to admit to the Saga University as a Monbusho scholar. Also acknowledge Dr. Thrishantha Nanayakkara, postdoc fellow at John Hopkins University, USA for his helping me to settle in Japan. Prof. J. R. Lucas, and Prof. Priyantha D. C. Wijetunge are also remembered for writing their valuable recommendations that helped me a lot to go on with graduate studies.

Mr. Sanath Jayawardena, Mr. Lanka Udawatta, Mr. Koliya Pulasinghe, Mr. Sherwin Guirnaldo, and Mr. Duminda Nishantha are also acknowledged for thesis proof reading and valuable comments. Without them this thesis would not have been in this clarity. Mr. Simon M. Tulloch of University of Durham, UK, is warmly acknowledged for his suggestions.

A big thank-you should go to all my Japanese friends for their kind friendship and company. You have looked after me as one of your family members, it made me feel that there was always somebody who cares about me.

The Ministry of Education, Culture, Sports, Science, and Technology of Japan, and Saga Prefecture Administration is also acknowledged for providing financial assistance for doctoral studies. It helped me save more time and concentration for research.

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