AN ADVANCED TRAJECTORY PLANNER FOR INDUSTRIAL ROBOT MANIPULATORS

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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...

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