Time Optimal Trajectory Planning For Redundant Robots Joint Space Decomposition For Redundancy Resolution In Non Linear Optimization Bestmasters

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Time-Optimal Trajectory Planning for Pick-and-Transport Operation with a Mobile Manipulator

CPC: Complementary Progress Constraints for Time-Optimal Quadrotor Trajectories

Introduction to Trajectory Optimization

Lecture 21: Trajectory Planning Time-optimal trajectory planning for multi-vehicle at an unsignalized intersection **Modern Robotics, Chapter 9.4: Time-Optimal Time Scaling (Part 1 of 3)** Tractor-Trailer Vehicle Trajectory Planning in Narrow and Cluttered Environments *Modern Robotics, Chapters 9.1 and 9.2: Point-to-Point Trajectories (Part 1 of 2) Trajectory Planning for Robot Manipulators* Towards Time-Optimal Trajectory Planning for Pick-and-Transport Operation with a Mobile Manipulator Lecture 8: Trajectory Planning Time-optimal trajectory planning for quadrotor maneuver November 2020 Plan With Me Bullet Journal Hobonichi Weeks | how I plan my monthly and weekly

MIT Robotics Team 2015 Promo Video*Must Have Planner Sections For A Functional \u0026 Productive Planning System | Plan With Bee Robotics Trajectory Planning - SixtySec*

Modern Robotics: Introduction to the Lightboard**MATLAB \u0026 Simulink Tutorial: Quadrotor UAV Trajectory and Control Design (PID + Cascaded)**

Modern Robotics, Chapters 9.1 and 9.2: Point-to-Point Trajectories (Part 2 of 2)

How to Create MATLAB GUI - robot arm simulation *-Kinodynamic Trajectory Optimization and Control for Car-Like Robots Tutorial: Gait and Trajectory Optimization for Legged Robots* Modern Robotics, Chapter 9.4: Time-Optimal Time Scaling (Part 2 of 3) **Finding Optimal Path Using Optimization**

Toolbox *Optimal trajectories for time-critical street scenarios using discretized terminal manifolds Planning, Fast and Slow: A Framework for Adaptive Real-Time Safe Trajectory Planning* teb_local_planner - An Optimal Trajectory Planner for Mobile Robots Modern Robotics, Chapter 9.4: Time-Optimal Time Scaling (Part 3 of 3) *Time-optimal path parameterization in SO(3) and SE(3) Time-optimal trajectory generation for landing a quadrotor onto a moving platform* **Time Optimal Trajectory Planning For**

However, to maximize productivity, the travel-time of the trajectory must be minimized. Optimized solutions for time-optimal trajectory planning that include robot dynamics, based on the seminal work in , , , generally require a large computational burden, unsuited to commercial use . As a result, commercially available online implementations for industrial robot motion planning typically do not fully utilize the dynamic capacity of the robot as proposed in these works.

Online near time-optimal trajectory planning for ...

Time-optimal trajectory planning for tractor-trailer vehicles via simultaneous dynamic optimization Abstract: Trajectory planning is a critical aspect of autonomous tractor-trailer vehicle design. Trajectory planning algorithms usually compute paths first, trajectories are obtained thereafter.

Time-optimal trajectory planning for tractor-trailer ...

An efficient time-optimal trajectory planning algorithm is proposed which improves total time significantly.•We consider differential-driven wheeled mobile robots' dynamics with motor dynamics ...

Time-Optimal Trajectory Planning for Adaptive Control of ...

In this paper, we show that, even in case of robots with flexible joints, the time-optimal trajectory planning problem can be recast into a non-convex problem in which the non-convexity is still ...

(PDF) Time-Optimal Trajectory Planning for Flexible Joint ...

The time-optimal control objective is cast as an optimization problem by using cubic splines to parametrize the state space trajectory. The optimization problem is solved using the flexible tolerance method. The experimental results presented show that the planned smooth trajectories provide superior feasible time-optimal motion.

Smooth and time-optimal trajectory planning for industrial ...

The fast simulation results of unicycle provide very useful information for time-optimal lane-change trajectory planning along parametric polynomials under the steering space and kinodynamic constraints represented by the velocity and acceleration bounds: the decrease of path length and the maximum curvature along the path is most relevant to decrease the travel time cost.

Time-Optimal Trajectory Planning along Parametric ...

►Velocity, acceleration and jerk of each joint are all both continuous and bounded. ►Initial and ending velocity, acceleration and jerk of each joint can be configured. ►Minimum-time optimal trajectory planning is achieved under kinematic constraints.

Time-optimal and jerk-continuous trajectory planning for ...

Shi et al. proposed to apply quintic non-uniform rational B-spline (NURBS) to construct curves for manipulator trajectory planning with respect to multi-objective (time optimal, energy optimal and smoothness optimal). Comparing with 5th order B-spline, quintic NURBS makes the trajectory more flexible and easier to be modified but also requires more complicated mathematical modelling because its mathematical forms involve n weights to be calculated.

Optimal time-jerk trajectory planning for industrial ...

Therefore, the study of trajectory planning for autonomous driving can refer to current studies on the trajectory planning of intelligent robots. 1 –9 The problem of trajectory planning for autonomous driving can be regarded as a time–space curve optimization problem in a two-dimensional plane, and solving the optimization problem means solving the problem of trajectory planning for ...

An optimal trajectory planning algorithm for autonomous ...

The optimal trajectory planning problem for multiple trains under fixed block signaling systems and moving block signaling systems has been investigated. Four solution approaches have been proposed: the greedy MILP approach, the simultaneous MILP approach, the greedy pseudospectral approach, the simultaneous pseudospectral method.

Optimal Trajectory Planning and Train Scheduling for ...

Time-optimal motion planning is significant for maximizing the productivity efforts of robotic systems. Furthermore, today efforts have been made to develop manipulators with high numbers of degrees of freedom (DoF) that can be used in rescue missions, inspection and manipulation in quite complex pipe installation, and nuclear energy installations [1] either moving autonomously or by remote control.

Time-optimal trajectory planning for hyper-redundant ...

A novel trajectory planning approach is presented suitable for online industrial robot applications along short path segments such as spot-welding. The proposed method generates trajectories that are computationally efficient, dynamically near time-optimal, and maintain path-following integrity in high-frequency planning-and-control cycles.

Online near time-optimal trajectory planning for ...

Through a nonlinear change of variables, the time-optimal trajectory planning is transformed here into a convex optimal control problem with a single state. Various convexity-preserving extensions...

(PDF) Practical time-optimal trajectory planning for ...

In this paper, a time-optimal trajectory planning method based on quintic Pythagorean-Hodograph (PH) curves is proposed to realize the smooth and stable high-speed operation of the Delta parallel robot. The trajectory is determined by applying the quintic PH curves to the transition segments in the pick-and-place operation trajectory and the 3-4-5 polynomial motion law to the trajectory.

Time-Optimal Trajectory Planning for Delta Robot Based on ...

In this letter, we show that, even in case of robots with flexible joints, the time-optimal trajectory planning problem can be recast into a non-convex problem in which the non-convexity is still given by bilinear constraints. We performed experimental tests on a planar 2R elastic manipulator to validate the benefits of the proposed approach.

Time-Optimal Trajectory Planning for Flexible Joint Robots ...

Conversely, we present here a time-optimal trajectory planning algorithm for robots with multiple exible joints and capable of considering and satisfying constraints on both the link and the motor variables. The main contribution of the paper is the translation of the minimum-time optimization problem with the inclusion

Time-Optimal Trajectory Planning for Flexible Joint Robots

Optimal motion planning is very important to the operation of robot manipulators. Its main target is the generation of a trajectory from start to goal that satisfies objectives, such as minimizing...

(PDF) OPTIMAL TRAJECTORY PLANNING OF MANIPULATORS: A REVIEW

2. Time-Optimal Trajectory Planning Based on the Cubic Spline. Generally speaking, to reduce the impulse shock to robot joints, ensuring the end effector of robots moving smoothly, a higher-order smooth function

should be chosen as the interpolation function, which is devoted to calculate the interpolating trajectory between given points.

A Dual-Thread Method for Time-Optimal Trajectory Planning ...

This paper shows the planning of time-optimal trajectories, which allows an autonomous race car to drive at the handling limits, taking into account locally changing road friction values.

This master's thesis presents a novel approach to finding trajectories with minimal end time for kinematically redundant manipulators. Emphasis is given to a general applicability of the developed method to industrial tasks such as gluing or welding. Minimum-time trajectories may yield economic advantages as a shorter trajectory duration results in a lower task cycle time. Whereas kinematically redundant manipulators possess increased dexterity, compared to conventional non-redundant manipulators, their inverse kinematics is not unique and requires further treatment. In this work a joint space decomposition approach is introduced that takes advantage of the closed form inverse kinematics solution of non-redundant robots. Kinematic redundancy can be fully exploited to achieve minimum-time trajectories for prescribed end-effector paths.

In this dissertation, we study two important subjects in robotics: (i) time-optimal trajectory planning, and (ii) optimal control synthesis methodologies for trajectory tracking. In the first subject, we concentrate on a rather specific sub-class of problems, the time-optimal trajectory planning along predetermined geometric paths. In this kind of problem, a purely geometric path is already known, and the task is to find out how to move along this path in the shortest time physically possible. In order to generate the true fastest solutions achievable by the actual robot manipulator, the complete nonlinear dynamic model should be incorporated into the problem formulation as a constraint that must be satisfied by the generated trajectories and feedforward torques. This important problem was studied in the 1980s, with many related methods for addressing it based on the so-called velocity limit curve and variational methods. Modern formulations directly discretize the problem and obtain a large-scale mathematical optimization problem, which is a prominent approach to tackle optimal control problems that has gained popularity over variational methods, mainly because it allows to obtain numerical solutions for harder problems. We contribute to the referred problem of time-optimal trajectory planning, by extending and improving the existing mathematical optimization formulations. We successfully incorporate the complete nonlinear dynamic model, including viscous friction because for the fastest motions it becomes even more significant than Coulomb friction; of course, Coulomb friction is likewise accommodated for in our formulation. We develop a framework that guarantees exact dynamic feasibility of the generated time-optimal trajectories and feedforward torques. Our initial formulation is carefully crafted in a rather specific manner, so that it allows to naturally propose a convex relaxation that solves exactly the original problem formulation, which is non-convex and therefore hard to solve. In order to numerically solve the proposed formulation, a discretization scheme is also developed. Unlike traditional and modern formulations, we motivate the incorporation of additional criteria to our original formulation, with simulation and experimental studies of three crucial variables for a 6-axis industrial manipulator. Namely, the resulting applied torques, the readings of a 3-axis accelerometer mounted at the manipulator end-effector, and the detrimental effects on the tracking errors induced by pure time-optimal solutions. We therefore emphasize the significance of penalizing a measure of total jerk and of imposing acceleration constraints. These two criteria are incorporated without destroying convexity. The final formulation generates near time-optimal trajectories and feedforward torques with traveling times that are slightly larger than those of pure time-optimal solutions. Nevertheless, the detrimental effects induced by pure time-optimality are eliminated. Experimental results on a 6-axis industrial manipulator confirm that our formulation generates the fastest solutions that can actually be implemented in the real robot manipulator. Following the work done on near time-optimal trajectories, we explore two controller synthesis methodologies for trajectory tracking, which are more suitable to achieve trajectory-tracking under such fast trajectories. In the first approach, we approximate the discrete-time nonlinear dynamics of robot manipulators, moving along the state-reference trajectory, as an affine time-varying (ATV) dynamical system in discrete-time. Therefore, the problem of trajectory tracking for robot manipulators is posed as a linear quadratic (LQ) optimal control problem for a class of discrete-time ATV dynamical systems. Then, an ATV control law to achieve trajectory tracking on the ATV system is developed, which uses LQ methods for linear time-varying (LTV) systems. Since the ATV dynamical system approximates the nonlinear robot dynamics along the state-reference trajectory, the resulting time-varying control law is suitable to achieve trajectory tracking on the robot manipulator.

The ATV control law is implemented in experiments for the 6-axis industrial manipulator, tracking the near time-optimal trajectory. Experimental results verify the better performance achieved with the ATV control law, but also expose its shortcomings. The second approach to address trajectory tracking is related in spirit, but different in crucial aspects, which ultimately endow this approach with its superior features. In this novel approach, the highly nonlinear dynamic model of robot manipulators, moving along a state-reference trajectory, is approximated as a class of piecewise affine (PWA) dynamical systems. We propose a framework to construct the referred PWA system, which consists in: (i) choosing strategic operating points on the state-reference trajectory with their respective (local) linearized system dynamics, (ii) constructing ellipsoidal regions centered at the operating points, whose purpose is to facilitate the scheduling strategy of controller gains designed for each local dynamics. Likewise, in order to switch controller gains as the robot state traverses in the direction of the state-reference trajectory, a simple scheduling strategy is proposed. The controller synthesis near each operating point is an LQR-type that takes into account the local coupled dynamics. The referred PWA control law is implemented in experiments for the 6-axis manipulator tracking the near time-optimal trajectory.

The experimental results show the feasibility and superiority of the PWA control law over the typical PID controller and the ATV control law.

A modern and unified treatment of the mechanics, planning, and control of robots, suitable for a first course in robotics.