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DESIGN NONLINEAR MODEL PREDICTIVE CONTROLLER FOR SPACE REDUNDANT MANIPULATORS

Abstract

Due to the particular harsh environment of space and the increasing demands of satellite maintenance, on-orbit refueling and assembly etc., the application of space robot has been received significant attention. Conventional linear controllers (e.g. PID) are not really suitable for the control of space manipulators due to the highly nonlinear behavior of the space robot model. Model predictive control (MPC) has been used in the chemical process control industry with great success; however, the application of predictive control in the aerospace industry appears relatively new. In principle, MPC is a feedback control scheme, for which in each sampling period, a finite horizon optimization problem is solved. One of the main benefits of predictive control is that the constraints on the inputs and outputs of the system can be explicitly considered in the control problem formulation.

This study investigates the use of nonlinear model predictive control (NMPC) for space redundant manipulators to approach an un-cooperative target satellite in space environment. The objective is to evaluate the performance of the predictive controller for the approaching task and to investigate the need and feasibility of incorporating constraints into the controller. The nonlinear dynamic model of an n-link manipulator is firstly recalled, which is then linearized and decoupled by feedback. Secondly, a nonlinear model predictive control scheme, implemented with an optimized dynamic model and running within small sampling period, is exhibited. The derived nonlinear predictive control law uses a quadratic performance index of the predicted tracking error and the predicted control effort. The constrained predictive controller solved a quadratic programming problem at every sampling interval as receding horizon.

The real-time implementation is based on Matlab/Simulink with the model predictive controller and computed torque controller. Major simulation results performed by using a 7 degree-of-freedom (DOF) redundant manipulator mounted on a 6 DOF spacecraft prove the effectiveness of the proposed control method. The NMPC and the widely used computed torque control (CTC) are compared. Tracking performance and robustness with respect to external disturbance or errors in the model are enlightened. Asymptotic error tracking and constraint handling results particularly demonstrate the effectiveness and potential of the nonlinear model predictive controller for the space redundant manipulators.