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MODEL PREDICTIVE CONTROL BASED ON RECURRENT NEURAL NETWORK FOR REUSABLE LAUNCH VEHICLE WITH DYNAMICS UNCERTAINTIES

Abstract

As a highly nonlinear system with large-scale and rapid state variations, the dynamic model of reusable launch vehicle (RLV) contains aerodynamic coefficients uncertainty and actuator saturation constraint. A model predictive control (MPC) method for RLV with a recurrent neural network (RNN) in the loop is presented in this paper since MPC is an effective control method for handling nonlinear and constrained system. Although rolling optimization and feedback mechanism of MPC could partly compensate for model uncertainties and disturbances, the prediction model of MPC still needs to be accurate enough. Therefore, an RNN is built as an approximator for RLV dynamic model which can be influenced by unmodeled dynamics and external disturbances. Meanwhile, RNN owns a higher computing efficiency as a substitute for conventional dynamic model, since computation of neural network is much easier than solution of differential equations. The predictive control law designed for a RLV in this paper takes over 3 degree of freedom trajectory tracking control and 3 degree of freedom attitude maneuver control, which can be regarded as outer loop and inner loop to control, respectively. The objective function of optimization for trajectory tracking control is composed of trajectory tracking errors together with variation of control inputs, and the optimal results of this outer loop are used as inputs of the inner attitude control loop while a similar MPC optimization problem is stated for attitude control loop. In finite predictive horizon of MPC, an RNN with the number of hidden layer neurons equal to the dimension of state vector is designed as a substitute for the prediction model. Based on the structure of RNN, the inputs of hidden layer neurons are composed of the last state vector and current control inputs, which makes weight matrix update of these two signals directly determine RNN approximation accuracy of RLV dynamic model with parametric uncertainties and external disturbances. According to the Lyapunov synthesis method, a stable updating law of weight matrices is derived by introducing errors between prediction model and real system. Then this error decrease can lead to rejection of unmodeled uncertainties and disturbances, so the robustness of corresponding MPC is strengthened. Finally, simulation results of RLV trajectory tracking and attitude control show the effectiveness of the designed control method and the robustness to parameters variation and external disturbances.