Koopman-Operator-Based Model Predict Control for Attitude Dynamics on *SO*(3)

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Abstract. Attitude dynamics has strong nonlinearity. It is very attractive to use the theory of linear systems to predict, estimate and control strongly nonlinear attitude dynamics by reconstructing nonlinear systems in a linear framework using data-driven methods. In this paper, the nonlinear attitude dynamics on *SO*(3) are identified and controlled based on Dynamic Mode Decomposition (DMD). Using the manually constructed nonlinear function dictionary as observation, the system approximation is obtained by the Extended Dynamic Mode Decomposition with control (EDMDc) algorithm, and a linear MPC controller is designed based on the EDMDc model. Considering the actual data always contains noise and the sensitivity of the original DMD algorithm to noise, the total least squares DMD (tls-DMD) is used to process the data containing noise. Finally, the effectiveness of MPC control is verified by simulation calculation.

Introduction

The attitude control system is a critical component of a spacecraft. In existing studies, Euler angles, modified Rodrigo parameters or quaternion are usually used to describe spacecraft attitude. However, the singularities of Euler angles and modified Rodrigo parameters exist. Two sets of quaternions correspond to the same attitude, and the continuous attitude control law based on quaternions may have the unwinding phenomenon. Another reason why attitude control on *SO*(3) still attracts wide attention is the difficulty caused by strong nonlinearity. In 1931, Koopman proved that the behavior of a nonlinear system can be represented by an infinite-dimensional linear operator acting on the observables (or measurement functions) of system states. It is very attractive to use the theory of linear systems to predict, estimate and control strongly nonlinear attitude dynamics by reconstructing nonlinear systems in a linear framework using data-driven methods.

Main result

The extended state is constructed by taking the polynomial of the original state as the nonlinear observation function, and the EDMD algorithm is used to identify the attitude dynamic system from the simulation data. Considering that the global prediction range of EDMD model under extended basis is limited, MPC control is adopted. The sequential quadratic programming (SQP) algorithm is used to optimize the cost function. Stochastic simulation results show that the controller can adjust the attitude to the desired position in a short time. If the data contains noise, tls-DMD is used to eliminate the impact of noise to a certain extent. Although the tls-DMD model has worse accuracy, MPC based on tls-DMD model is still feasible. Some simulation results are shown as follows.

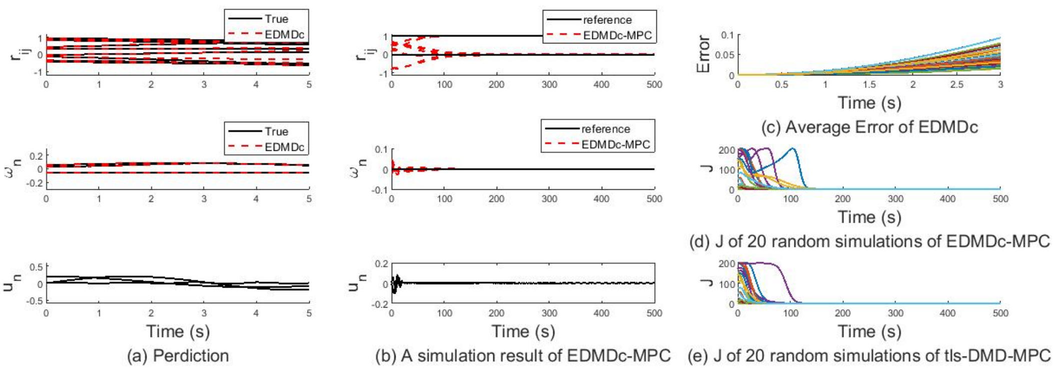

Figure 1: EDMDc model of Attitude dynamics on SO(3)

References

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