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ROBUST POWERED DESCENT GUIDANCE USING SUCCESSIVE CONVEXIFICATION AND TUBE MODEL PREDICTIVE CONTROL

Abstract

Reliable powered descent guidance is crucial for both reusable rocket landing and planetary landing. This paper presents a tube model predictive control (MPC) based method for the robust powered descent guidance under external disturbances. The powered descent guidance is often formulated as a deterministic optimization problem. However, various uncertainties, such as uncertain initial conditions and random winds, significantly affect the accuracy of precise soft landing and may even lead to mission failure. Therefore, this paper first develops a robust optimization framework based on tube invariant set. This ensures that the system remains within the invariant tube set around the generated trajectory in the presence of disturbances. Secondly, building upon convex optimization, the paper introduces tube-based model predictive control using successive convexification to realize optimal fuel usage or optimal landing accuracy. Furthermore, while most previous studies focused on the analysis under the three-degree-of-freedom (3-DoF) model, a coupled six-degree-of-freedom (6-DoF) dynamical model better reflects real-world scenarios. Thus, within the aforementioned framework, this paper extends the 3-DoF to 6-DoF, obtaining a more realistic robust powered descent guidance method based on tube MPC. In simulation, the paper first presents the results of 3-DoF robust powered descent guidance, validated using monte carlo methods. It then provides robust trajectory optimization results under the 6-DoF dynamical model, demonstrating through monte carlo simulations that the system can still maintain its trajectory within the designated invariant tube set in the presence of disturbances. A comparison with successive convexification method that do not consider uncertainties illustrates the effectiveness of the proposed robust powered descent guidance method. Finally, the paper compares the robust MPC with a classic MPC and provides corresponding simulation results. In conclusion, the proposed tube MPC based method effectively addresses the powered descent guidance problem under disturbances and extends to a more realistic 6-DoF dynamical model. The method proposed in this paper contributes to enhancing landing safety and robustness.