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MULTI-CONSTRAINED REAL-TIME ENTRY GUIDANCE USING DEEP NEURAL NETWORKS

Abstract

Real-time trajectory planning is essential for autonomous, adaptive, and reliable entry flight for hypersonic vehicles. The existing trajectory planning techniques, which are traditionally divided into indirect and direct methods, suffer drawbacks including unpredictable iterative process and computational time, no guarantee of convergence to the optimal or even feasible solutions, and requirement of good initial guesses. To address these issues, a multi-constrained entry guidance approach is proposed to achieve real-time control for hypersonic vehicles using the deep neural network (DNN) technology. Additionally, a constraint management algorithm and a predictive lateral guidance algorithm are also developed to enhance the flight safety. This study focuses on the following three contributions: First, the entry trajectory optimization problem is formulated as a root-finding problem based on an improved compound bank corridor, and a DNN is developed to learn the nonlinear functional relationship between the control input and the corresponding range. Supported by sufficient samplings and training, the well-trained DNN can accurately approximate the ranges concerning different control profiles during the flight. Consequently, the flight control system can adjust the control instructions in real time according to the actual flight range requirement. Second, a constraint management algorithm based on state feedback techniques is developed to deal with the issue of constraints violations in extreme flight conditions. Without affecting the overall performance of the DNN-based trajectory controller, this constraint management algorithm is capable of updating the control instructions according to the flight states with guaranteed satisfaction of constraints. Third, a predictive lateral guidance algorithm is developed to determine the bank reversal of flight control using a cross-range proportional decrement strategy. Simulations are conducted to demonstrate the performance of the newly proposed DNN-based entry guidance approach on providing highly precise, reliable, and robust entry flight for hypersonic vehicles with a significant advantage on real-time performance.