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LAUNCH VEHICLE ADAPTIVE FLIGHT CONTROL WITH INCREMENTAL MODEL BASED HEURISTIC DYNAMIC PROGRAMMING

Abstract

This paper presents an innovative adaptive flight control algorithm for launch vehicles. Spaceflight is one of the greatest technological achievements of humankind. It is used in space exploration, launching communication satellites and space telescopes, and also to make observations from a different perspective of the phenomena that occur on Earth. One of the most difficult tasks in these activities is to control a launch vehicle to fulfill the mission requirement. This challenge is caused by the wide flight envelope, highly nonlinearity, and aerodynamic uncertainties. The existing method applied to launch vehicle flight controls is gain scheduling. However, this approach incurs the huge pre-launch cost for evaluating and testing the flight control system. Therefore, this paper aims to develop a nonlinear self-adaptive flight control algorithm for a wide range of launchers.

Approximate dynamic programming has been introduced to provide a model-free, adaptive process for optimal control. A widely used structure for nonlinear systems is Heuristic Dynamic Programming (HDP). HDP separates the evaluation and improvement with a critic and an actor, which are usually implemented with artificial neural networks (ANNs). A model network is also needed to maintain the backpropagation pathway of the actor error. However, the online identification of the global model is not a trivial task especially when the system is nonlinear. It often needs a certain time to approximate an appropriate model with ANNs. Therefore, HDP methods usually require off-line training beforehand, which is also difficult without an accurate simulation model. Furthermore, identifying the global model will cause extra computational burden. The incremental control technique, on the other hand, can be used to deal with system nonlinearity without identifying the global system. This technique approximates a time-varying linearized model of the original system with a sufficiently high sample rate for discretization.

This paper uses online identified incremental models instead of the global model network in the conventional HDP method, which is called Incremental model based Heuristic Dynamic Programming (IHDP). Compared to the conventional HDP method, IHDP method can accelerate the online learning and improve the precision with the online identified incremental model. The result of an illustrative application validates that IHDP method outperforms the conventional HDP method on the precision, the settling time, and the robustness. It also shows that the newly developed IHDP control strategy is very suitable for complex launch vehicle flight control.