論文の内容の要旨

論文題目　Stochastic Optimal Control for Aircraft Conflict Resolution in the Presence of Uncertainty
(不確実環境下における航空機のコンフリクト回避のための確率的最適制御)

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In this dissertation, probabilistic aircraft conflict detection and resolution algorithms in the presence of uncertainties are proposed. In order to accommodate the increasing air traffic and alleviate the workload of air traffic controllers, the proposed conflict detection and resolution algorithms can provide the automated advisories and conflict resolution trajectories for the air traffic controllers and pilots and have a potential to ultimately replace the tasks of the air traffic controllers. First, a spatially correlated wind model is used to describe the wind uncertainty, which is the primary uncertainty compared to other possible uncertainties such as navigation errors and pilots' intents. On the basis of stochastic aircraft dynamics containing the uncertainty, a probabilistic conflict detection algorithm using the polynomial chaos expansion method is proposed. The polynomial chaos expansion algorithm can quantify uncertainties in complex nonlinear dynamical systems with high computational efficiency. In addition, a numerical algorithm that incorporates the polynomial chaos expansion algorithm into the pseudospectral method is proposed to solve the conflict resolution problem as the stochastic optimal control problem. The stochastic optimal control method is combined with the proposed conflict detection algorithm to solve the conflict resolution problem under the wind uncertainty. Moreover, a stochastic near-optimal control method is proposed to generate conflict resolution trajectories and maneuvers in real time without actually solving the computationally expensive stochastic optimal control problems. The proposed near-optimal conflict resolution algorithm is based on a surrogate modeling technique called polynomial chaos kriging, which is used to construct the surrogate models of the optimal conflict resolution trajectories from a set of precomputed optimal solutions. The near-optimal conflict resolution trajectories can be accurately generated in real time from the surrogate models with the information of current conditions (e.g., current states). The proposed near-optimal conflict resolution algorithm has the feature of optimal feedback control. When the states on the precomputed optimal trajectory deviate from the actual states due to the uncertainties, the proposed near-optimal feedback control method can accurately generate the near-optimal trajectory starting from the actual states in real time without solving another stochastic optimal control problem to obtain the correct optimal trajectory. Through illustrative aircraft conflict detection and resolution examples, the performance and effectiveness of the proposed conflict detection and resolution algorithms are evaluated and demonstrated.