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A ROBUST FILTER METHOD FOR DYNAMIC PRESSURE MEASUREMENT AIDED NAVIGATION FOR MARS ENTRY

Abstract

Complete observability of dynamic system and high precision is a major concern of future Mars entry navigation. This paper proposes a dynamic pressure measurement aided integrated navigation scheme for Mars entry navigation. The dynamic pressure derived from the Mars Entry Atmospheric Data System (MEADS), the triaxle accelerations from inertial measurement unit (IMU), and the relative distance and velocity between the probe and Mars orbiter are integrated in a filter as navigation measurements to increase the observability of the dynamic system and perform state estimation. The observability matrix of the nonlinear dynamic system is derived with Lie algebra based on the quadratic approximation, and the inverse of the condition number of the observability matrix is used to define the degree of observability for the navigation system. Due to the change of the external environment and aerodynamic coefficients of the probe, the dynamic system of the integrated navigation scheme suffers various model parameters deviations, such as the Mars atmospheric density, lift-to-drag ratio, and ballistic coefficient, which will affect the state estimation accuracy of the integrated navigation scheme. In order to reduce the impact of model parameters deviations on state estimation for the proposed integrated navigation scheme, we propose a robust navigation filter. First, the Mars entry dynamic model and perturbation caused by parameters uncertainties are built, and an intermediate variable is defined to reduce the number uncertain variables. Then, a robust divided difference filter (DDF) with analytical filter gain is derived by minimizing the cost function consisting of the trace of the posterior estimation error covariance matrix penalized by the trace of the state metric matrix to model deviation. Contrast to the traditional DDF method, the cost function of the robust DDF is constructed by the trace of the estimation error covariance and the weighted uncertain parameter sensitivity matrix, and the weighted matrix is attenuated with an exponential decay coefficient, which is determined adaptively with entry time. Computer simulation results demonstrate that, on the one hand, the proposed integrated navigation scheme can ensure the complete observability of the dynamic system; on the other hand, the robust DDF is less sensitive to uncertain parameters than the standard DDF, and can accurately estimate the state even though multiple model uncertain parameters are taken into consideration.