Paper ID: 28836
student

ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (1) (7)

Author: Mr. Zhengshi Yu
School of Aerospace Engineering, Beijing Institute of Technology, China

Prof. Pingyuan Cui
School of Aerospace Engineering, Beijing Institute of Technology, China
Mr. Shengying Zhu
School of Aerospace Engineering, Beijing Institute of Technology, China

ESTIMATION ERROR LOWER BOUND ANALYSIS FOR MARS ENTRY NAVIGATION

Abstract

In order to improve the navigation capability in the Mars entry phase, a navigation scenario based on radiometric measurements to multiple beacons has been proposed. However, the evaluation of the navigation performance is a difficult task due to the highly nonlinear dynamic and observation equations and probable non-Gaussian model and measurement noises. Although Fisher information matrix has been proven to be an efficient method to estimate the error lower bound, the dynamic model which is also an important contributor to the estimation accuracy is not considered during the derivation of traditional Fisher information. Focusing on the numerical computation of Fisher information matrix and corresponding error lower bound for a nonlinear navigation system, a novel particle-based computation method is proposed in this paper. The need for linearization and the assumptions on Gaussian errors and algebra dynamic model are not necessary. In the algorithm, Sequential Importance Resampling is used to approximate the posterior probability density function of the state corresponding on available previous measurements and to prevent the sample depletion. However, the expression of the probability density function is still discrete. Therefore, the Kernel Density Estimation technology is then employed to transform the discrete probability density function to a twice differentiable one. The sequential Fisher information matrix can thus be derived. First of all, the simulation results from a linear Gaussian system demonstrate the feasibility and accuracy of using proposed computation method to capture the posterior probability density function and the Cramér-Rao lower bounds. Both stability and accuracy of the method are improved significantly with the increase of number of particles. Furthermore, the estimation error lower bounds of the Mars entry navigation scenario using radiometric measurements from three ground beacons are estimated and analyzed based on the proposed numerical computation method. The simulation results indicate that the proposed method is an efficient tool to analyze the performance of nonlinear navigation system. Meanwhile, the determinant of Fisher information matrix, which is a metric quantifying the degree of observability, shows that the sequential Fisher information matrix is more adaptable and comprehensive for observability analysis due to the consideration of the contribution of dynamic model. Moreover, it can be concluded that both measurement noise and the propagation of states have impact on the navigation performance.