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RESEARCH ON UPF OBSERVABILITY ANALYSIS- BASED AUTONOMOUS NAVIGATION METHOD FOR DEEP SPACE

Abstract

In order to reduce the complexity and cost of the deep-space exploration missions, the realization of detector autonomous (all or part of the system) has become an inevitable choice, and autonomous navigation system is the premise condition of autonomous operation, so the autonomous navigation methods gradually become a deep space exploration mission research focus. For deep space autonomous navigation system, since the distances between the detector and the central celestial body or the navigation target celestial body can not be measured directly, the generally way is that utilize the state estimation algorithms to process images, angle, sight line direction and the other measurement information, so as to calculate the position and velocity of the detector. However, whether the orbit parameters can be calculated with the measurement information mainly depends on the observability of the system, and if navigation system is un-observability, the orbit will not be estimated. Therefore, the observability analysis of the deep space autonomous navigation system becomes a key issue. The traditional method of observability analysis is that make the system linearization and discretization, then utilize the liner and discrete system observability theory to analyze the observability of the navigation system, but, for an observable continuous system, the discretization operation may not be able to maintain its observability. So, for application, there are many limitations in the traditional method of observability analysis. In this thesis, based on the observability analysis of the nonlinear system, the observability matrix is derived from the theory of differential geometry. Then, a method for measuring the observability index of the system is derived, and the analytical method of the observability index for state variable is given. The principle is applied in the autonomous navigation system for deep space. The observability indexes of navigation system corresponding to different observation models are studied, and the observability indexes of the orbital elements are investigated. The result of the observability analysis is used as a selection criterion of the observation model used in the navigation system. And then, the navigation approaches under different observation models are established by utilizing the UPF (unscented particle filtering). Finally, the autonomous navigation approach presented in the paper is validated by the practical data of a deep impact mission. The relation between the observability index of the navigation system and the estimation accuracy of orbit elements is verified, and the method of observability analysis is demonstrated to be feasible.