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INTER-NODE STATE ESTIMATION METHOD FOR SMALL FLEXIBLE LANDERS IN ASTEROID MISSIONS

Abstract

Asteroid landing missions provide significant scientific value in understanding the origins of the solar system and the evolution of life. Successful missions have been carried out by the United States, Japan, and Europe, while China is also actively pursuing its own plans for asteroid sampling return and comet fly-by. To increase the reliability and safety of asteroid landings, a flexible landing scheme that employs small landers constructed with flexible materials has been discussed in the literature recently. The advantages of small flexible landers include reduced weight and cost, increased reliability, and improved adaptability to unexpected landing conditions, such as uneven landing sites or deviations in terminal states. This kind of landers are particularly well-suited for landing on asteroid with low gravity or tough terrain.

For small flexible landers in asteroid mission, autonomous navigation is required due to long communication delays and huge costs of ground-based navigation. Multiple optical sensors (referred to as measurement nodes) are used for autonomous navigation. However, deformation of flexible materials may lead to unknown changes of inter-node states, hindering information fusion between nodes. Therefore, estimating inter-node states is a crucial step in autonomous navigation. This paper proposes an inter-node state estimation method for small flexible landers, which combines a neural network for relative state propagation with multi-node optical feature matching. Firstly, an inter-node state propagation neural network is designed based on the multiple-layer perceptron structure. The network uses finite element models to generate training samples, and introduces a state constraint mapping unit to ensure that the results of inter-node state propagation comply with the physical characteristics of flexible landers. Next, as the size of small flexible landers is limited, the field of view (FOV) of different measurement nodes would be partially-overlapped. Thus, optical geometric constraints can be built through feature matching of overlapped FOVs, providing valuable information for state estimation between nodes. Finally, an Unscented Kalman filter for inter-node state estimation is established to integrate state propagation with onboard optical observations. Mathematical simulations show that the proposed method can accurately estimate the inter-node states of small flexible landers, enabling effective autonomous navigation during asteroid landing.