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DATA-BASED SPACE DEBRIS TRAJECTORY EVOLUTION PREDICTION AND SPACECRAFT FORMATION ENCIRCLEMENT PATH PLANNING METHOD

Abstract

With the explosive growth of space exploration technology, the frequency and complexity of space activities have significantly increased, inevitably accompanied by an increase in the number of non-functional spacecraft and debris in orbit, posing an increasingly serious threat to operational satellites and missions. Therefore, the mitigation and restoration of space debris have become a worldwide concern. One of the primary challenges in approaching and capturing space debris is its non-cooperative characteristic and complex external disturbances, which cause the considerable uncertainty of dynamics model parameters and relative states, unable to accurately predict its trajectory.To address these issues, a data-driven evolution method is proposed to predict the forward reachable set (FRS) of space debris. This method enables the over-approximation of the short-term trajectory set of debris in the absence of the dynamics model information. Furthermore, a spacecraft formation optimization planning algorithm is proposed to achieve the encirclement and capture of debris. To design an appropriate cost function, multiple objectives in the space mission is considered, including position and velocity synchronization, collision avoidance between formation members and debris' FRS, and other relevant factors. The conflicts between these tasks were resolved by assigning corresponding weights to different objectives. Finally, we incorporate an neural adaptive dynamic planning method based on a critical neural network, which can enable efficient and optimal coordination among multiple mission objectives, significantly improving the formation system's operational autonomy. The efficacy of the proposed scheme are validated through several simulation scenarios.