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Author: Ms. Wen ya Wan
National Key Laboratory of Aerospace Flight Dynamics, Northwestern Polytechnical University, Xi'an, China

Dr. Chong Sun
Northwestern Polytechnical University, China
Prof. Jianping Yuan
National Key Laboratory of Aerospace Flight Dynamics,Northwestern Polytechnical University,Xi'an, China
Dr. Yao Cui
Northwestern Polytechnical University, China

LEARNING-BASED ADAPTIVE WHOLE-ARM GRASPING METHOD FOR DYSFUNCTIONAL SATELLITE CAPTURE MISSION

Abstract

Along with the rapid growth of space exploration, more and more dysfunctional satellites are generated, which not only occupy valuable orbits but also threaten the safety of operational satellites. However, due to the lack of grappling points and uncertainty of the motion parameters, capturing a dysfunctional satellite becomes an emerging challenge. Taking advantages of the extreme flexibility and hyper-redundancy of the hyper-redundant manipulator, a learning-based adaptive whole-arm grasping method is proposed in this paper. There are three main steps in the proposed method. Firstly, the dysfunctional satellite grasping problem is modeled as a Markov decision process. Specifically, both the degrees of freedom of the hyper-redundant manipulator and the dysfunctional satellite are chosen as the states of the Markov decision process. As a result, the dysfunctional satellite dynamics and uncertainty can be exploited during the whole grasping process, which guarantees a robust grasping procedure. Secondly, in order to judge if a valid capture of a dysfunctional satellite is obtained automatically, existing metrics on a valid capture (i.e., force and form closure) are transformed into reward functions of the Markov decision process. Finally, the reinforcement learning algorithm is adopted to search the valid grasping policy intelligently, and contact locations on the dysfunctional satellite and hyper-redundant manipulator can be determined. Compared with traditional grasping strategy, the main advantage of the proposed method lies in treating the problem of finding contact locations and the grasping approach as a completely integrated process. Consequently, without requiring grappling points and accurate information, the hyper-redundant manipulator adaptively wraps its whole body around the dysfunctional satellite to grasp it robustly. In addition, as the hyper-redundant manipulator has extreme flexibility, the proposed method can apply for dysfunctional satellites with different geometries. To demonstrate the superior of the proposed method, several study cases have been designed and simulated. The results indicate that the proposed method is better on dealing with uncertainty and adapting dysfunctional satellites with different geometries compared with the traditional grasping method.