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Author: Mr. An Zhu
Fuzhou University, China

Prof. Li Chen
Fuzhou University, China
Prof. Xiaoyan Yu
Fuzhou University, China

DUAL-ARM SPACE ROBOT WITH SPRING-DAMPER DEVICE CAPTURING SATELLITE OPERATION BUFFER AND COMPLIANCE REINFORCEMENT LEARNING CONTROL

Abstract

With the deepening of human space exploration, a large number of satellites are launched into space every year. It is inevitable that a small part of satellites will fail to enter the intended orbit or damage in orbit. If they can be recovered, the cost of space exploration will be greatly saved. At present, using space robot to capture failed satellites has broad application prospects. Compared with the single-arm space robot, the dual-arm space robot is gradually becoming the focus because of its high flexibility, greater load, and multi-functional. Generally, the process of capture operation can be divided into four stages: observation, approach, collision, and stability control. The impact force is easy to damage the joint of space robot in the third stage, and the impact effect will make the hybrid system difficult to realize stabilization in the fourth stage.

Based on this, a spring-damper device (SDD) is designed between joint motor and manipulator. The device can not only absorb and digest the impact energy, but also limit the joint impact force to a safe range through reasonable and coordinated design the compliance strategy. Firstly, the subsystem dynamic models of dual-arm space robot and satellite before collision time are derived by using Lagrange function based on dissipation theory and Newton-Euler function respectively. Secondly, based on the momentum conservation, the position and velocity constraints of closed chain system, the closed-chain hybrid system of space robot and satellite is obtained after capture. The actor-critic reinforcement learning control scheme can optimize itself through trial-and-error and interaction with dynamic environment, has strong environmental adaptability. Therefore, for realize stabilization of the hybrid system, a reinforcement learning control scheme based on fuzzy wavelet network is proposed, and the controller consists of a performance measurement unit, an associative search network (ASN) and an adaptive critic network (ACN). The controller obtains the primary reinforcement signal through the performance measurement unit, then using the ACN to construct a more informative signal than the primary reinforcement alone to tune the ASN realize the stability control of the hybrid system. Finally, through the numerical simulation of the dual-arm space robot capturing satellite operation, SDD can effectively reduce the joint impact force in the third stage, and reduce 52.3