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Author: Dr. Zixuan Zheng
Northwestern Polytechnical University;National Key Laboratory of Aerospace Flight Dynamics, China

Dr. Jian Guo
Delft University of Technology (TU Delft), The Netherlands
Prof. Jianping Yuan
China

DEVELOPMENT OF COOPERATIVE CONTROL AND PLANNING TECHNIQUES FOR A HETEROGENEOUS SMALL SATELLITE SWARM

Abstract

Nowadays, with the development of modern technology, more and more spacecrafts have been launched to provide civil services or military purposes. The rising number of on-orbit spacecrafts cause the number of space debris increases, leading to the severe orbital congestion. Considering this, engineers and scientists have developed space robotic arms to capture on-orbit targets and to control them, such as ETS-7 mission, Orbital Express mission, and CanadArm2 mission. Although these missions have successfully performed on-orbit target capture, few of them has considered targets as non-cooperative. Non-cooperative targets (NCTs) are space objects which are not designed for regular capture missions, including space debris, malfunction satellites, or hostile spacecrafts. Targeting increasing needs for NCTs capture and removal missions, researchers have developed many techniques to capture an NCT, including using space robots, space net, tentacles gripper, tether gripper, and harpoon. However, to successfully capture an NCT, three scientific problems need to be solved in advance, identification of NCTs' key parameters, approaching and docking between chaser and the NCT, and the post-capture phase control, respectively. This paper proposed a collaborative planning and control technique for a heterogeneous satellites swarm (called "Hyenas") to ensure the sustainable and efficiency of on-orbit NCTs capture missions. This swarm consists of three types of satellites, one is called "Spy Satellite (SS)", second one is called "Observation Satellite (OS)", and third one is called "Capture Satellite (CS)". The SSs are responsible for close range evaluation of an NCT and provide its basic information. Then, OSs need to perform detailed observation on the NCT, which is to gather its key parameters for the capture phase The CSs are designed to perform capture motions, the needed satellites number and capture configuration is also optimized based on the NCT's key parameters. The proposed technique uses machine learning and swarm intelligence algorithm to ensure the heterogeneous small satellite system can collaborate and generate suitable control sequences for NCT capture missions. To demonstrate the superior of the proposed swarm, several kinds of NCTs have been considered as study cases. The simulation results indicate that for the same NCT, comparing with ordinary techniques (e.g. robotic arm, net, harpoon), the HS is easier to deploy and capture. For different NCTs, HS do not need to change basic settings and simply just increase or decrease the number of CSs, which makes HS has high flexibility which basically can be used to capture any size of NCTs