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COORDINATED CAPTURE OF A PASSIVE SPACE OBJECT USING AUGMENTED STATE ESTIMATION AND NEURAL NETWORKS

Abstract

Autonomous on-orbit servicing and assembly of large space structures are at the forefront of research for advancing space exploration beyond low-earth orbit. Current autonomous relative navigation techniques are insufficient for use in proximity operations between multiple spacecraft which require coordinated, precise and instantaneous state estimation. A solution to this problem will provide the basis for achieving sustainable, affordable and productive space-based construction and maintenance without the need for human-in-the-loop systems. The system of study involves two spacecraft performing coordinated capture of a passive object, robust to an unknown dynamic environment and communication interruptions. The challenges accompanying coordinated capture include timing and maintaining an accurate knowledge of the relative position and orientation between the spacecraft as they approach and initiate a grasp on the passive object. Failure to coordinate the spacecraft properly could result in a collision which could damage the spacecraft and terminate the mission. Existing research on this topic is concentrated on the manipulation of large space structures using a team of robotic spacecraft assuming capture has already taken place. Additionally, the problem of autonomous rendezvous and docking has not yet reached maturity for systems with no human intervention. This paper combines an augmented state estimation approach and a Neural Extended Kalman Filter (NEKF) to improve the tracking of the partner spacecraft while reducing uncertainties of the dynamic environment. The navigation system of each spacecraft incorporates the estimated control inputs of the partner spacecraft, allowing for increased redundancy if communication between the pair is delayed or interrupted. Additionally, adapting the Kalman filter to include neural network training of the observed system dynamics yields a system that is robust to modelling error and stochastic environments such as that of deep space. The implementation of these algorithms improved estimation accuracy for each spacecraft and enabled precise tracking of the partner spacecraft to successfully coordinate the capture of the passive object. The additional functionality of the augmented state estimation coupled with the NEKF increases redundancy of the navigation system, resulting in a more reliable architecture for coordinated proximity operations.