IAF SPACE OPERATIONS SYMPOSIUM (B6)
Innovative Space Operations Concepts and Advanced Systems (2)

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COLLISION AVOIDANCE MANOEUVRE AUTOMATION WITH DEEP REINFORCEMENT LEARNING

Abstract

With the increase in space traffic in Low Earth Orbit associated with the New Space era, it is necessary to reconsider operational procedures to address Collision Avoidance Manoeuvres (CAMs). This new environment brings about an increase in conjunction alerts, necessitating the automation of tasks and protocols to alleviate the burden on operators' capabilities. Moreover, adequate treatment of uncertainty, including both aleatory and epistemic types, should be considered to make robust decisions that address worst-case scenarios in given conjunctions. In this paper, the authors propose a deep learning-based CAM system to enhance the capabilities of CASSANDRA, an intelligent agent designed to handle Space Traffic Management scenarios, automating the design of avoidance strategies.

CASSANDRA combines the Dempster-Shafer theory of evidence with machine learning techniques to robustly and promptly address satellite conjunctions and provide decision-making support to operators, in both single and multiple event scenarios. The current implementation provides event classification based on the risk level and confidence in the provided information. The objective is to further develop autonomous execution of CAMs by cascading the current outcome of CASSANDRA into a safe Deep Reinforcement Learning (DRL) layer, which should provide a robust avoidance action when necessary.

DRL techniques are employed to optimise a cost function that includes terms for propellant consumption and collisions. The pipeline follows this procedure: available encounters, like synthetic observations real and virtual Conjunction Data Messages (CDMs), are ingested into CASSANDRA to evaluate their risk based on belief states. For cases requiring CAMs, the belief state is passed to the DRL layer to design the best avoidance action. A final step is added to ensure the safety of the manoeuvre.

The methodology is illustrated with numerical cases using realistic simulated observations and real CDMs to train DRL models. The performance of different models on new encounters is analysed to determine the degree of successfully avoided encounters and the safety of proposed solutions. This methodology is then compared with standard approaches based on orbit optimization to evaluate similarity in provided solutions and savings in computational time.