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COLLISION AVOIDANCE ALGORITHMS FOR SPACE TRAFFIC MANAGEMENT APPLICATIONS

Abstract

Commercial space utilisation finds itself in a defining moment. Space-based assets are experiencing an accelerated growth due to technological enablers, such as cheaper and more flexible satellite platforms and more affordable launch opportunities, as well as due to high-societal-impact applications, such as communications, navigation, or Earth observation. Like air transport in the 40s, this blooming of the so-called NewSpace should be nurtured through adequate international cooperation efforts analogous to those which ultimately led to current air traffic management systems.

Establishing a cost-effective network of Space Traffic Management (STM) systems faces diverse challenges, from technical and operational aspects, to regulatory, policy and legislation. Focusing on the technical part, new types of missions and platforms and more objects in orbit will increase collisional activities and require advances in space situational awareness and space surveillance and tracking. To deal with the growing amount of data, fast and efficient algorithms paired with artificial intelligence methods are a must. Furthermore, autonomous on-orbit collision avoidance capabilities would reduce the workload on satellite operators and improve safety. Finally, a more congested scenario calls for global approaches, where the analysis of an avoidance manoeuvre is not limited to the two objects involved but the general effect on the environment.

To tackle some of these issues, this work presents recent advances and new developments in collision avoidance manoeuvres modelling, analysis and optimisation. The focus is put on computational efficiency, suitability for autonomous on-board applications, and synergies with artificial intelligence. To achieve these goals analytical and semi-analytical models are sought for, leveraging different perturbation methods like averaging or multiple scales. Both impulsive and low-thrust propulsion systems are considered, as well as maximum deviation or minimum collision probability optimal manoeuvres. Furthermore, the models can also be applied to uncertainties propagation. The resulting algorithms are then tested in different practical scenarios and traded-off for computational performance, accuracy and reliability. Based on the results, their applicability for future STM systems is discussed. Finally, the work also devotes attention to the global effect of a collision avoidance manoeuvre in other objects not involved in the original conjunction.