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APPLICATION OF ACTIVE FEEDBACK CONTROL FOR INVESTIGATION OF DEBRIS MITIGATION STRATEGIES ON A DENSITY-BASED MODEL OF THE POPULATION EVOLUTION

Abstract

The population of objects in space faced an unforeseeable growth in the last decades. At the beginning of the space era, Earth's orbital environment appeared as an infinite resource. When the IADC guidelines for limiting the space debris proliferation have been defined in 2002, less than 10000 objects were tracked orbiting our planet. As of today, the count has risen to more than 30000 objects. Therefore, it is now imperative to reiterate the guidelines and reconsider the approach to the problem. Different counteractions are available to deal with the situation. However, how to efficiently combine and apply these methods for a sustainable utilisation of the space environment is still an open question. Fast and systematic analyses are required to characterise the evolution of such a rapidly changing environment and the predicted effectiveness of possible mitigation measures. To respond to this need, the GREEN SPECIES project funded by the European Research Council will develop a "Robust control of the space debris population to define optimal policies and an economic revenue model for sustainable development of space activities". In this paper, the space population growth problem is reformulated adding an active feedback control on the environment, in which mitigation and remediation measures become control inputs to the system, mimicking human actions in space and on mission design. The feedback controller, which may be a PID or LQR one, acts through the inputs on the objects' distribution around Earth by selecting the most promising strategy to reach a target scenario. Consequently, leveraging on the versatility of the approach, combinations of multiple inputs can be analysed, and different performance indices targeted. A simplified definition of the population evolution in low Earth space is used in this preliminary phase; debris and intact objects move in a one-dimensional domain in orbital radius, which is binned in spherical shells. The evolution of the environment is modelled in terms of the objects' density dynamics. The system includes the effect of atmospheric drag, objects' sources as launches and in-orbit fragmentations, and artificial sink mechanisms such as post mission disposals. The resulting set of ordinary differential equations is integrated with an active feedback controller that tunes the deposition and removal inputs to reach a predefined target. The tool exploits the benefits of control techniques to investigate the effectiveness of diversified rules in space and time to mitigate the debris proliferation and its risk to missions in low Earth orbit.