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SMALL SATELLITE OPERATIONS PLANNING FOR AGILE DISASTER RESPONSE USING GRAPH THEORETICAL TECHNIQUES

Abstract

Agile, manoeuvrable satellite constellations have the potential to fundamentally change space mission design by moving away from traditional missions, designed to address predicted demand, and instead providing responsive systems that can react to real-time events, such as natural disasters. The unique advantages of responsive constellations are enhanced by the use of small satellites, whose short development times and low cost can offset the increased risk and shorter mission life inherent in the use of manoeuvrable spacecraft. In addition, newly developed, highly efficient propulsion systems can provide small satellites with agile manoeuvrability for low propellant mass. Previous work by the authors has developed a fully analytical method of designing efficient, low-thrust responsive manoeuvres using such systems and has applied this to the challenge of providing rapid flyover of targets on the Earth. This allows consideration of multiple targeting options, each of which can be performed using a range of manoeuvres that have different flyover times, view angles, and propellant requirements. However, to effectively implement an agile satellite system requires a long-term, holistic understanding of the concept of operations. This holistic view must consider the flow of information from spacecraft tasking, to target overflight, through to data downlink. To facilitate this, the existing analytical methodology has been combined with graph theoretical techniques to allow the complex trade-space to be perceived as a graph. The connections in the graph, representing possible manoeuvres, are rapidly traversed to identify favourable routes to achieve the desired goal. The effect of changes in mission priorities can be assessed by reweighting the graph, avoiding the need to recalculate the manoeuvre options. Preliminary studies have shown that a long-term assessment considering a sequence of manoeuvres is necessary to ensure efficient operations planning. For example, selecting a favourable manoeuvre to acquire data from a target can ultimately result in greater data latency if the satellite subsequently requires a long time to over-fly a ground station. By including the full data lifecycle from source to sink and exploring long-term operational choices, the proposed methodology provides a framework for small satellite mission operations incorporating responsiveness. A disaster response scenario in which frequent imagery of a target, such as a forest fire, is required to aid first responders will demonstrate the effectiveness of the method.