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AUTOMATED RESIDENT SPACE OBJECT CATALOGUE CONSTRUCTION AND MAINTENANCE USING OPTICAL SENSOR MANAGEMENT

Abstract

The ability to accurately determine current and future positions of manmade space objects, known as Space Situational Awareness, is an active area of research. This is largely due to the increased dependence on satellites by military and commercial sectors.

This paper describes the development and testing of a real-time optical space surveillance system, designed to construct and maintain a catalogue of resident space objects in geostationary orbit.

The system represents the state and uncertainty of an object using particles and employs a particle filter for state estimation. The use of particle filters allows for a comprehensive representation of the probability distribution of the state that accurately reflects the uncertainty in the measurement data and the motion of the objects. Initial orbit determination is done using Bayesian statistical analysis (Markov Chain Monte Carlo) with bounds on the apogee and perigee of the orbit which constrains the system to consider objects which are close to geostationary. A precise representation of uncertainty enables more accurate inferences on the objects in the catalogue, such as better accuracy of probability of conjunction.

Rather than maintaining the orbital states of all objects in the same way, by explicitly controlling the sensor resources this system allows the uncertainty in orbital state to be managed independently for each object. The uncertainty is permitted to grow and is refined through measurement only when needed; for example if data association problems may occur in the future, or the uncertainty grows outside of a single field of view. Following control theoretic principles, situations when orbital states need to be refined are formulated into cost functions. The sensor is scheduled to reduce this cost function over a non-myopic horizon. Feedback from the sensor is used to dynamically change the sensor schedule as orbital state estimations evolve and new objects are detected. Time that is not required for refining existing objects is used to grow the surveillance region and explore for previously undetected objects.

We use real-world testing to demonstrate that the system is able to efficiently allocate resources to create and maintain a catalogue of the order of 100 space objects with relatively low revisit rates; reducing sensor load and increasing the proportion of time allocated to search for new objects.