SPACE DEBRIS SYMPOSIUM (A6)
Poster Session (P)

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MODELING THE COMBINATORIAL COMPLEXITY OF A NEW DATA ASSOCIATION TECHNIQUE USED WITH NARROW FENCE-TYPE RADAR SYSTEMS FOR SMALL LEO DEBRIS CATALOGUING

Abstract

This paper deals with the issue of cataloguing small space debris using one or several narrow fence-type radars (radars with a field of regard of narrow elevation and wide cross-elevation). Indeed, the use of a narrow fence-type radar should ensure a better feasibility and thus enable the detection and cataloguing of smaller Low Earth Orbit (LEO) objects more easily. However, this option involves Short Arcs (SA) of trajectories, which cannot be handled by existing association techniques (especially in the track initiation) because of the resulting prohibitive combinatorial complexity. Recently, we have proposed and investigated an association technique able to initiate tracks from SAs while keeping the combinatorial complexity under control. Following on from that, the benefits of using a system of two narrow fence-type radars could possibly bring should be assessed. Indeed, a second sensor could reduce significantly the time lapse before an additional informative SA is acquired and reduce the combinatorial complexity as a result. In this paper, we propose and investigate a new method in order to analyze the functioning of our SA association technique on different sensor setups with regard to the combinatorial complexity. First, we show that the combinatorial complexity can be modeled as a polynomial expression depending on the density of detections and the number of considered scans, assuming that a set of three SAs is required to enable a proper orbit determination as shown in several recent or earlier studies. In the case of a gating method, the exponent related to the number of scans can be reduced at the cost of introducing multiplicative constants. Since these constants reflect the average ambiguity of an association and the average new-object detection rate, they provide a fair description of the combinatorial complexity involved by the investigated association technique. Then, we simulate the detections outputted from three different sensor setups and apply the association technique mentioned previously. The combinatorial complexities of the three sensor setups are predicted for different detection densities and compared to simulation experiment results in order to support the validity of this model. Finally, the estimated combinatorial complexities are extrapolated to the expected actual detection density in the case of the small debris (diameter between 1 and 10cm) in LEO, for the most relevant sensor setup.