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RANGE AND DOPPLER ENABLED INITIAL ORBIT DETERMINATION WITH LEOLABS RADARS

Abstract

With debris larger than 1 cm in size estimated to be over one million, precise cataloging efforts are essential to ensure space operations' safety. Compounding this challenge is the 'oversubscribed problem,' where the sheer volume of space objects surpasses ground-based observatories' observational capacity. This results in sparse, brief observations and extended intervals before image acquisition. LeoLabs' network of phased-array radars addresses these needs by tracking sub-10 cm objects in Low Earth Orbit (LEO) with 10 independent radars across six sites.

Currently, the sensors provide very precise range and Doppler measurements, and less precise azimuth and elevation. For this reason, the tracklets are only used to refine existing orbits. At the same time, none of the literature approaches to perform initial orbit determination (IOD) is adequate to handle such observations, as they usually deal with angles-only, radar-only, or doppler-only measurements.

While LeoLabs tracklets are extremely short, they hold much more information than typical observations at each instant in time. For this reason, we do not label them as too-short arcs (TSAs), and using the Admissible Region (AR) approach would be improper. Thus, this paper develops a tailored approach to initialize state and uncertainty from a single tracklet, and subsequently enable data association thanks to the dense radar measurements availability from LeoLabs' sensors.

Starting from the accurate range measurements at the first and last timestamp, the angular measurements are used as an initial guess to obtain a Lambert arc over the measurement's span. The angles are then refined by minimizing the residuals on the accurate range and Doppler measurements over the first, middle, and last timestamps. In this way, an IOD solution is obtained. Lastly, through Differential Algebra (DA), the IOD will not be just a point but the region of all solutions that fit the available measurements within a prescribed accuracy, namely an orbit set (OS). This practice, widely used in previous research, allows for efficient data association of different tracklets, thus enabling the addition of accurate tracks to the catalog following their independent initialization.

The algorithm's efficacy is tested using real measurements from various radar sites, evaluating the IOD solution's accuracy and its ability to predict the next passage from a single tracklet.