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MULTI-SENSOR TRACKLET ASSOCIATION CONSIDERING SPATIOTEMPORAL DEVIATION CALIBRATION

Abstract

The number of space objects increased exponentially in recent years due to the development of several LEO constellations and break-up events. Monitoring a large number of space objects using optical surveillance sensors may generate many short-arc observations, namely tracklet. Tracklet Association (TA) is a prerequisite of orbit determination, target identification, and catalog maintenance. However, a challenge emerges in the process of associating tracklets from multiple sensors, where some systematic spatiotemporal biases caused by environmental influences, time drift, and attitude positioning errors are always overlooked in applications. Consequently, biased data may lead to incorrect associations, while utilizing error-associated tracklets for spatiotemporal deviation correction may result in inaccurate outcomes. If the problem of multi-sensor TA and spatiotemporal bias calibration can be resolved simultaneously, the accuracy of TA and orbit determination can be further enhanced.

To overcome this challenge, this paper develops a multi-sensor TA and spatiotemporal calibration joint optimization method. The principle of the optimization involves incorporating spatiotemporal biases as variables for optimization. The optimal solution is identified when a bias, added to measurements for compensation, maximize the likelihood of associating tracklets within a reasonable limit. To this end, the likelihood of association is assessed through the Mahalanobis distance between the measured and estimated angular-rate information, where the latter can be generated through the Boundary-Value Problem (BVP). For each hypothetical bias that employed in optimization, a corresponding BVP can be established and addressed to evaluate whether such a bias confirms or rejects the association of the two tracklets. Therefore, a user defined threshold can be applied to determine if the association and spatiotemporal deviation calibration are well accepted.

The developed method is compared with the traditional TA methods using two simulation scenarios. The first case considers the TA of 100 randomly selected space objects form NORAD public catalog, the new approach demonstrates a consistent TA accuracy with traditional methods, affirming its effectiveness in typical scenarios. The second case employs constellation targets, and results validated that the proposed approach exhibits higher accuracy compared to traditional methods, and the spatiotemporal biases can also be accurately estimated.