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Author: Dr. Yang Yang
RMIT University (Royal Melbourne Institute of Technology), Australia, yiyinfeixiong@gmail.com

Mr. Han Cai
Royal Melbourne Institute of Technology (RMIT) University, Australia, caihanspace@gmail.com
Mr. Xuechuan Wang
Texas Tech University, United States, wangxuechuan1991@163.com
Dr. Baichun Gong
Nanjing University of Aeronautics and Astronautics, China, baichun.gong@nuaa.edu.cn
Dr. Robert Norman
Space Environment Research Centre Ltd. (SERC), Australia, robert.norman@rmit.edu.au

BOUNDARY VALUE APPROACH FOR BIRTH MODELLING IN MULTIPLE SPACE OBJECT TRACKING

Abstract

Modelling birth of new objects is of a necessity for multiple space object tracking. Given only optical tracking observations, the state-of-the-art techniques for birth modelling consist of methods based on the constrained admissible region (CAR) and probabilistic admissible region (PAR), which have been developed to approximate the probability density function of the initial orbital state of a tracklet via a Gaussian mixture (GM) formulation for initialisation of multi-object tracking filters. Meanwhile, we authors have also developed a novel birth model based on the boundary value problem (BVP) optimization approach. The BVP approach leverages two arcs of measurements to obtain a deterministic initial orbit determination (IOD) solution, while CAR/PAR yields GM form of the initial object state based on a single arc.

In the previous work, the BVP optimization method seeks to determine the optimal range pair that yields the best fitting IOD solution to both tracklets. Then the boundary positions can be calculated. A non-perturbed Lambert solver is adopted to obtain the boundary velocities so that a complete hypothetical IOD solution is generated. The associated covariance is estimated by using a batch least squares (BLS) processor, initialised by two tracklets, their IOD solution and a priori covariance matrix.

In order to improve the accuracy of IOD estimation for the birth object, this work eliminates the assumption of two-body dynamics in the Lambert solver and considers more realistic perturbation forces, e.g., high degree/order Earth gravity model. This is achieved by leveraging the shooting method with orbit propagation via the newly developed feedback-accelerated Picard iteration method. This collocation method has the advantage of very efficient and highly accurate long-term integration of the perturbed orbital equations, which is beneficial to handle long observational gaps. Also, an unscented transformation is introduced into the BVP optimisation process to yield the corresponding covariance matrix of the IOD solution. Hence, the accuracy of the covariance estimation will be also improved compared to the original linear BLS solver.

The new BVP approach is incorporated into the labelled multi-Bernoulli filter for multiple space object tracking. Scenarios of tracking objects in both the geosynchronous Earth orbit and geosynchronous transfer orbit are used to demonstrate the improvement in terms of Optimal Sub-Pattern Association errors of multi-object state and cardinality estimations.