15th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Orbit Determination and Propagation (9)

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

Mr. Han Cai
Royal Melbourne Institute of Technology (RMIT) University, Australia

ANALYSIS OF ADAPTIVE GAUSS MIXTURE UNSCENTED KALMAN FILTER WITH SPARSE OPTICAL OBSERVATIONS FOR ORBIT DETERMINATION

Abstract

The increasing amount of space debris poses significant threats to our space assets. In order to avoid collisions with space debris, the acquisition of highly accurate and reliable orbital information of these threatening objects is necessary. With the available ground-based facilities, various types of observations are obtained to aid orbit determination (OD).

A main caveat of optical observations (i.e., angles and angular rates) is that the distance between the space object and the ground station is unknown. This factor can result in significant errors in obtaining the full information of the orbital state. One possible approach to address this is to introduce physical constraints to reduce the space of possible orbits, which is referred to as the admissible region (AR) technique. Additionally, for many real space debris tracking campaigns, limited observation times and short visible arcs lead to sparse observational data for a specific space object, which present more challenges to the OD problem. If there are large gaps between any two consecutive tracking arcs, the imperfect orbital dynamics with uncertain orbital parameters (e.g., atmospheric drag (AD) and solar radiation pressure (SRP) coefficients) degrades the prediction accuracy and contributes to filter divergence.

This paper presents an adaptive Gaussian mixture unscented Kalman filter (AGMUKF) to tackle this OD problem, and conducts a robustness analysis of OD with respect to initial conditions and the sparsity of optical observations. The initial orbital state is represented by a constrained AR (CAR) or a probabilistic AR (PAR) based on optical observations and additional physical constraints, i.e., semi-major axis and eccentricity. For the CAR, all points within the constraints are considered as equally probable, which yields uniform distributions of range and range rate. Then Gaussian mixture models (GMM) are used to approximate the CAR. Otherwise, the PAR is sampled using a Monte Carlo approach. Then GMM are used to approximate the particle clouds. Thus, an AGMUKF can be initialised thereafter with splitting, pruning and merging of GMM components at each follow-on observation epoch. Furthermore, uncertainties in AD and SRP coefficients are carefully treated to avoid state uncertainties to grow to very large levels during the observation outage. Their covariance is considered instead of estimating their values. Both simulated and real observations are used for demonstration and analysis. The real data were collected at Mount Stromlo for different orbit scenarios. The OD solutions provide reliable orbital information for the follow-on tracking and conjunction assessments.