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Author: Mr. Sean Hixon
Pennsylvania State University, United States, sxh5594@psu.edu

Mr. David Schwab
Pennsylvania State University, United States, dvs5558@psu.edu
Mr. Jason Reiter
Pennsylvania State University, United States, jar577@psu.edu
Dr. Puneet Singla
Pennsylvania State University, United States, psingla@psu.edu

CONJUGATE UNSCENTED TRANSFORMATION BASED SEMI-ANALYTIC APPROACH FOR UNCERTAINTY CHARACTERIZATION OF ANGLES-ONLY INITIAL ORBIT DETERMINATION ALGORITHMS

Abstract

Conventional initial orbit determination (IOD) methods result in a deterministic solution for orbit parameters without any knowledge of the associated uncertainty. The main objective of this paper is to develop a semi-analytical means to compute the uncertainty associated with the output of IOD algorithms. The main idea is to use the transformation of variables (TOV) method to compute the probability density function (PDF) associated with the orbit parameters (output of the IOD algorithms) as a function of the uncertainty in the angular observations. Generally, the application of the TOV method requires the computation of a sensitivity matrix for mapping between the observation (angular) space and the orbit elements, which is tedious to compute for a generic IOD algorithm. Building upon our prior work, we will utilize the non-product quadrature method known as the Conjugate Unscented Transformation (CUT) to compute these sensitivity matrices in a non-intrusive manner through the solution of a continuous least squares problem. For this purpose, the solution of an IOD algorithm is expanded in terms of orthogonal polynomial basis functions where the coefficients of the polynomial basis functions correspond to the higher order sensitivity of the IOD solution. The CUT method is utilized for the purposes of computing the multi-dimensional expectation integrals required to determine the unknown polynomial coefficients in a computationally attractive manner. The CUT method can be considered an extension of the well-known unscented transformation and provides the minimal points to compute the multi-dimensional expectation integrals of desired order polynomial functions with respect to Gaussian and uniform density functions. The main advantage of the proposed approach is that it will provide a unifying framework to accurately characterize the non-Gaussian uncertainty associated with any IOD algorithm. The provided orbit parameter state PDF can then be used to initialize sequential orbit determination algorithms (such as the Kalman filter) rather than depending upon artistic tuning. In particular, different orbits and observation geometries will be used to validate the developed approach.