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COVARIANCE ESTIMATION AND FUSION FOR EPHEMERIS-ONLY CATALOGUES APPLIED TO THE SPECIAL PERTURBATIONS CATALOGUE

Abstract

The availability of realistic covariance information for the orbit of every Resident Space Object (RSO) contained in a catalogue is of crucial importance for Space Situational Awareness (SSA) activities, e.g., collision avoidance services. The most comprehensive of these catalogues is the Special Perturbations Catalogue (SPCAT), maintained by the U.S. 18th Space Defense Squadron. The SPCAT is the high-precision ephemeris version of the TLE RSOs catalogue, publicly available on databases such as Space Track and Celestrak. However, covariance information is not provided with the SPCAT ephemerides' mean state. So-called observed covariance values can be obtained via a comparison procedure between consecutive orbit information updates referring to the same SPCAT RSO. This paper proposes new methodologies for calculating covariance values for catalogues deprived of such information, including the application and adaptation of existing data fusion methods from the literature. The main final goal is computing covariance matrices that are more realistic and reliable than those obtained with the currently available methods. Another key objective is the integration of the new methodology in an operational environment. Computational efficiency is then a relevant factor and, consequently, the baseline method to be developed is selected and then improved taking into account such efficiency criterion. A new routine that considers the Orbit Determination epoch of each RSO ephemeris arc to coherently combine covariances based on their propagation time is developed and implemented. Two fusion methods are deployed, Covariance Intersection (CI) and Covariance Union (CU), and the realism of the results is tested with a well-established metric, the Mahalanobis distance and its fitting of the Chi-square distribution according to appropriate Empirical Distribution Function tests such as Cramer-von Mises. The realism of the combined covariances is validated against precise ephemeris of LEO Sentinel satellites. While CI is proved inadequate as a stand-alone fusion method due to the characteristics of the SPCAT observed covariances, CU provides covariance values that are consistently more realistic than the ones obtained with the baseline method.