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SENSITIVITY AND COMPARISON OF ORBITAL STATE-BASED MANEUVER DETECTION APPROACHES

Abstract

Detecting and characterizing orbital manoeuvres is of key importance for many tasks related to Space Situational Awareness (SSA), such as space catalogue maintenance, or identification of anomalous behaviours and associated threats. Literature approaches for Manoeuvre Detection can be mainly classified based on the typology of input data: orbit-to-orbit methods rely on the analyses of time sequences of orbital parameters coming from different sources, such as Two Line Elements sets (TLE) (Patera et al., 2008), Orbital Mean Messages (OMM), Orbital Parameters Messages (OPM) and Orbital Ephemeris Messages (OEM); instead, track-to-orbit and track-to-track methods also exploit measurements from sensors (e.g., telescopes, laser ranging system and radars). Focusing on orbit-to-orbit methods, an additional classification can be done depending on whether or not orbital propagations are considered in the processing pipeline. Propagation-based methods (Shao et al.,2020, Lemmens and Krag, 2014) compute the differences between a propagated state and the corresponding one available from astrometric data at a certain epoch. Differences which are above an user defined threshold are flagged as manoeuvres. Derivative-based methods (Kelecy et al., 2007) (Patera et al., 2008) identify maneuvers as peaks in a difference function obtained by applying a moving window curve fit technique on a time sequence of astrometric data (e.g., expressed in terms of mean orbital parameters). There are also hybrid methods, which rely on both propagation and data fitting (Clark et al., 2020). The reliability of all these methods is affected by complex challenges mainly related to the noise in the available data, as well as to their frequency, and to the uncertainties of orbital propagations. In addition, the proper selection of algorithms' tuning parameters, e.g., thresholds, which allow correctly detecting manoeuvres while minimizing false alarms and missed detections without the use of a trained human operator, is a key requirement for the development of an autonomous manoeuvre detection tool. In this context, this paper compares different maneuver detection methods, both derivative and propagation-based, in order to find the most suitable one for various applications. The methods are compared in terms of accuracy and computational efficiency. Finally, an original approach to automatize the choice of the tuning parameter is proposed to generalize the detection process. The performance is assessed using both synthetic and real data. Numerical simulations are

carried out within a MATLAB-GMAT simulation environment considering test cases in different orbital regimes (i.e., LEO, MEO and GEO).