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PREDICTING THE PROBABILITY OF SATELLITE COLLISIONS USING BAYESIAN UNIVARIATE HIDDEN MARKOV MODEL

Abstract

Space is becoming more crowded in Low Earth Orbit (LEO) due to increased space activity. Such a dense space environment increases the risk of collisions between space objects endangering the whole space population. Therefore, the need to consider collision avoidance as part of routine operations is evident to satellite operators. Current procedures rely on the analysis of multiple collision warnings by human analysts. However, with the continuous growth of the space population, this manual approach may become unfeasible, highlighting the importance of automation in risk assessment. In 2019, ESA launched a competition to study the feasibility of applying machine learning in collision risk estimation and released a dataset that contained sequences of Conjunction Data Messages (CDMs) in support of real close encounters. The competition results showed that the naive forecast and its variants are strong predictors for this problem, which suggests that the CDMs may follow the Markov property. The proposed work investigates this theory by benchmarking Hidden Markov Models (HMM) in predicting the risk of collision between two resident space objects by using one feature of the entire dataset: the sequence of the probability in the CDMs. In addition, Bayesian statistics are used to infer a joint distribution for the parameters of the models instead of just obtaining point-wise estimates, which allows the development of robust and reliable probabilistic predictive models that can incorporate physical or prior knowledge about the problem within a rigorous theoretical framework and provides prediction uncertainties that nicely reflect the accuracy of the predicted risk. This work shows that, even though only one feature was analyzed, the implemented HMM outperforms the naive solution in some metrics, which further adds to the idea that the collision warnings may be Markovian and suggests that this is a powerful method to be further explored.