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IMPROVING SATELLITE ON-BOARD ORBIT ESTIMATION WITH ARTIFICIAL NEURAL NETWORKS

Abstract

Small and nano satellites have limited computational resources; as such, a high precision on-board trajectory estimation algorithm may prove difficult to implement. Furthermore, certain perturbative factors are difficult to accurately model (e.g., Earth's atmosphere, or Solar activity). Orbit predictions may be useful for the Guidance, Navigation and Control (GNC) subsystem; ideally, collision avoidance protocols must be initiated before the incident happens. Therefore, estimating the satellite's motion in time, fast enough and with an acceptable error (when considering the physical limitations of the power consumption), becomes essential. The paper proposes the use of artificial neural networks (ANN) together with a simplified orbit estimation algorithm; the simplified estimator integrates the satellite's equations of motion subject to gravitational perturbations resulting from: *third body motion (Sun's and the Moon's positions are considered), solar radiation pressure, atmospheric drag and the dominating term in the Earth's gravitational field equation.* The output of the estimator is a state-vector encapsulating the positions and velocities of the satellite, in time. Consequently, several ANN models were trained to give sparse compensating position estimations at fixed future moments in time; the compensations are additive to the projections of the position vector to the three axes of the reference system and can be defined using vector notation. This paper focuses on a two-hour estimated orbit, for which only six ANN predicted compensating position vectors proved to yield satisfactory results. The generation of these corrections is computationally inexpensive with respect to the numerical integration algorithm, since an ANN only feeds weighted sums through activation functions to compute the output. Using these predicted adjustments, an algorithm which interpolates a new orbit that is closer to the real trajectory is discussed. Simultaneously, the mathematical framework for the orbit interpolation is thoroughly argued. For the training and validation of ANN, real orbital data was collected from the GRACE-FO (European Space Agency) mission, which consists of two satellites revolving around the Earth in a low orbit. The ANN is trained with data samples collected from the first three weeks of June 2018 and the validation set consists of data collected from the last week of the same month. The results in the paper reveal that ANN can significantly improve on-board trajectory estimations. Generalization of the performance is also discussed.