Paper ID: 79100
student

21st IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Orbit Determination and Propagation - SST (9)

Author: Mr. Sajjad Kazemi
University of Waterloo, Canada

Prof. Nasser L. Azad
University of Waterloo, Canada
Mr. Haroon B. Oqab
Columbiad Launch Services Inc., Canada
Mr. George Dietrich
Columbiad Launch Services Inc., Canada

ENHANCEMENT OF ORBIT PREDICTION ACCURACY USING TRANSFORMER

Abstract

Space is now more congested and contested than ever before. The top priority for both public and private sectors is to ensure satellites operate collision-free. Hence, residence space object (RSO) orbit predictions with high accuracy as one of the challenging areas in space situational awareness (SSA) is critical. Errors accumulating over time and, subsequently, distorting the prediction are the most irritating drawback of the Simplified General Perturbations Orbit Model 4 (SGP-4) as an industry standard propagator of RSO orbits. To surmount SGP-4 imperfections, we expanded our recent study and implemented the vanilla transformer instead of long short-term memory (LSTM) and gated recurrent unit (GRU) networks in our prediction model. Unlike recurrent neural networks and their subsets, the transformer simultaneously ingests the input sequence data. Due to the functionality of the self-attention mechanism, it can also be trained by parallel processing, saving a significant amount of time. To the best of our knowledge, this research will be the first one that applies the transformer to the orbit prediction in the Low Earth Orbit (LEO). The developed model can predict RSOs' future trajectory for an extended time horizon. Both state vectors and Keplerian data sets have been used for the training. The hybrid SGP-4 interpolation, developed in our previous work, is deployed to transform unsynchronized and messy publicly available data sets to a synchronized and neat one that is up-sampled to a consistent time of one minute. The transformer ingests the resulting datasets to forecast the subsequent 10-day trajectory of any RSO according to its previous 10-day history input. Then, the model can employ its own forecasted data as a new input to predict RSOs' trajectories to further extend the prediction time horizon at the cost of losing accuracy. Moreover, using an innovative idea to feed the Sine and Cosine of the true anomaly as two new features, instead of the true anomaly itself, into the model during the training, the transformer model results in less error and improved accuracy in the prediction of this variable compared to previous studies. Through benchmarking the developed model against SGP-4 and comparing its accuracy with our available LSTM and GRU networks, the results show a promising performance of the transformer model. The trained model displays less mean absolute percentage error and an improved correlation between actual data and 10-day forecasted results compared to the SGP-4, LSTM, and GRU models.