

Abstract

Reliable maneuver detection is central to space situational awareness because unmodeled thrust quickly degrades orbit prediction and catalog maintenance. This thesis investigates maneuver and anomaly detection from satellite trajectory data. We first study unsupervised maneuver/anomaly detection using publicly available Two-Line Element (TLE) data.

To enable supervised learning despite scarce labels, we develop a high-fidelity simulator of maneuvering geostationary satellites and generate a dataset of synthetic satellite trajectories. We process these trajectories into synthetic ephemerides and demonstrate maneuver detection with a neural network model achieving an F_1 score of 0.79.

We further generate synthetic pseudo-TLE sequences by fitting Simplified General Perturbations 4 (SGP4)-compatible TLE parameters to masked ephemerides via constrained least squares and train Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), and transformer-based detection models. The best model reaches an F_1 score of 0.94 and Receiver Operating Characteristic (ROC)–Area Under the Curve (AUC) of 0.99 on a synthetic test set. We also present qualitative experiments on real observations and real TLE data.