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ROBUST TLE OUTLIER DETECTION ALGORITHM WITH MANOEUVRE DETECTION CAPABILITIES

Abstract

Two Line Elements (TLE's) are a means of describing the orbit of space objects. They are provided by the US Air Force through Space-Track where they can be downloaded. However, these TLE's are sometimes uploaded multiple times or contain erroneous data. If left unfiltered, these can lead to incorrect trajectory estimations which in turn leads to potentially inaccurate conjunction assessment.

To address this challenge, we present an outlier detection algorithm that applies a statistical sliding window approach with integrated manoeuvre detection capabilities. This method calculates the mean and standard deviation over a user-defined sliding window for the semi-major axis, eccentricity and inclination. It establishes the most likely interval for the next TLE observation. If a new observation falls outside this interval, it is temporarily labelled as an outlier and excluded from the dataset. To distinguish between anomalies and genuine orbital changes, the algorithm employs a consecutive outlier check: if the subsequent observation also falls outside the range, it is interpreted as an orbital manoeuvre, and both observations are reinstated and marked as such. Conversely, if the next observation lies within the expected range, the initial anomaly remains an outlier.

To enhance decision reliability, a confidence metric is assigned to each detected outlier. This metric quantifies the certainty of the anomaly by evaluating the deviation's magnitude relative to the expected bounds. This approach mitigates false positives caused by minimal deviations near zero standard deviation, ensuring that only high-confidence anomalies are excluded from the dataset. Conversely, severe outliers with a high confidence score are removed, as the likelihood of these being genuine anomalies is substantial.

This algorithm provides robust and fast outlier detection including manoeuvre detection capabilities. By accurately distinguishing between orbital manoeuvres and anomalous data points, it ensures a reliable dataset, a high level of orbit prediction accuracy and conjunction assessment reliability, ultimately supporting safer and more efficient space operations.