Spacecraft Data Wrangler

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Overview & Background

The Spacecraft Data Wrangler creates a streamlined way for non-experts to analyze satellite telemetry data. There is a large backlog of unparsed historical spacecraft data in many different formats. Our project deals with RINEX and TLE formats. This data is often populated with out-of-family anomalies — including environmental interference, known part defects, and manufacturing interference—which impede accurate analysis of GNSS information. To determine whether deviations in measurements are the result of noise or actual anomalies, we compare sensor data to prediction measurements utilizing spatial, clustering, and estimation outlier detection methods. All of our findings, including data parsing, analysis, and visualizations, are then displayed through our web application.

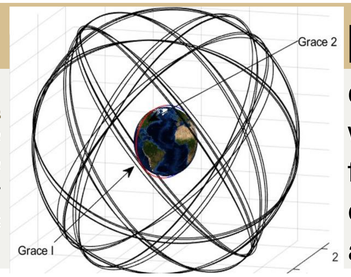

Fig 1 Grace relative to other satellites

Data Sources

This project deals with GNSS data drawn from NASA's Grace satellites, which return RINEX with signal to noise ratio (SNR) and pseudorange data fields. We also utilize outside data such as precise ephemeris (SP3) files from NASA's CDDIS to obtain accurate GPS states at any time.

Research Methodology & Results

This project is a RINEX data pipeline, going from unparsed data to visualizations through various methodologies.

Methodology 1: Keplerian Elements are extracted and compared with modeled expectations of anomalies to identify a reasonable bound for error. Sensor noise is then removed using a multidimensional Kalman filter.

Methodology 2: SNR is plotted by range and grouped by time. Every time the satellite becomes visible to GPS, this is denoted as a pass. Variability trends within these plots are studied for possible external interference.

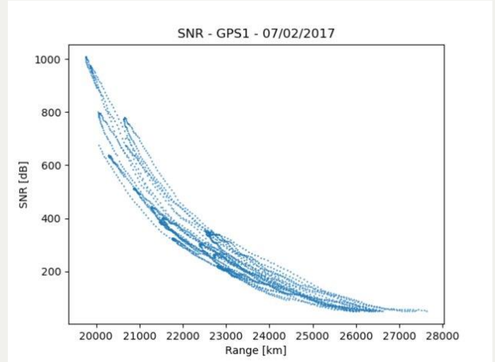

Fig 2 Anomalous SNR over a satellite pass

Fig 3 Geospatial Anomaly Detection: Average Signal Strength over Earth

Methodology 3: Data is plotted and analyzed using a binning strategy, grouping data into 2-degree bins by latitude and longitude and recording maximum signal strengths. Anomalies are then identified by looking for significant deviations in these maximum signals.

Data Pipeline

Raw Telemetry Data

RINEX & TLE from NASA's Grace mission And SP3 from the GNSS constellation

↓

Parsed RINEX data

Easily manipulated in a CSV format

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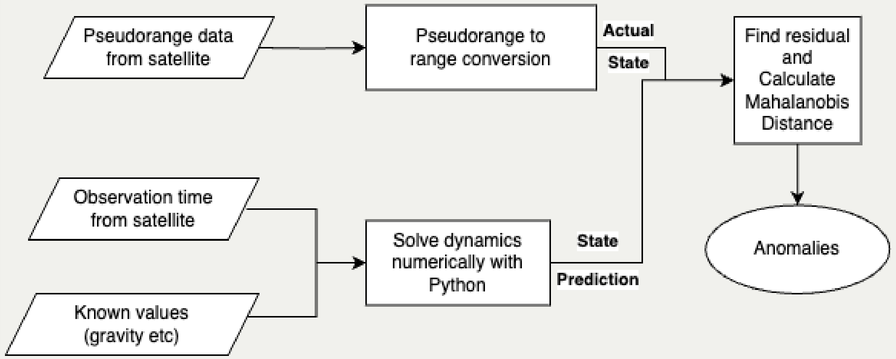
Visualizations

Observation vs. Time
Obs. vs Obs.
Geospatial Plots
SNR pass analysis
Pseudo range outliers

Fig 4 Anomalous Pseudorange Detection using Estimation Filtering



Conclusion

As a final step, the team created a web application that combines dynamics, estimation, and visualization into one comprehensive interface. The application can take in raw data, parse it, and process visualizations.

Currently, the team has two working filters that act on linear data. These filters are currently being expanded to apply to real-world data.

Future plans include incorporating more UI features into the interactive interface that allow the user to better alter the data, including more selections for data manipulation. We aim to add features to clean the data after parsing according to user specifications and additionally handle more forms of data.

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