Maneuver Detection Report

INTRODUCTION

This project focuses on analyzing historical orbital data to detect maneuvers in satellite trajectories. By examining variations in the semi-major axis (SMA), we aim to identify patterns associated with orbital adjustments. Understanding these patterns will enhance our ability to predict future maneuvers and support more effective mission planning. This analysis leverages historical data to provide valuable insights into satellite behavior and maneuver patterns.

OBJECTIVE

The primary objective of this project is to detect maneuvers in satellite trajectories by utilizing **Heuristic methods**. We aim to identify patterns in the historical orbital data, focusing on variations in the semi-major axis (SMA). By defining specific rules and thresholds, the heuristic approach will help us recognize significant changes indicative of maneuvers. Additionally, we seek to develop a system that predicts future maneuvers and assesses time intervals between detected maneuvers, thus improving our understanding of orbital dynamics and mission planning.

Reason for the Chosen Method

Initially, I considered **machine learning methods** for this project due to their ability to model complex patterns and make predictions based on extensive data. However, with only three data points indicating maneuvers, the **dataset was insufficient** to train an **accurate** machine learning model. Despite attempts to develop a model, the results did not meet the project's objectives.

Heuristic methods, on the other hand, offer several **advantages**. They are straightforward to implement and interpret, and they rely on well-defined rules rather than extensive training data. This makes them particularly effective when working with limited data. Heuristics also provide immediate insights based on established patterns and thresholds, which is crucial for this project.

Given the constraints of the dataset, the heuristic approach was selected as the most viable solution. Although I have a strong preference for machine learning due to my passion for the field, the heuristic method effectively addresses the project's needs and offers a practical solution given the available data.

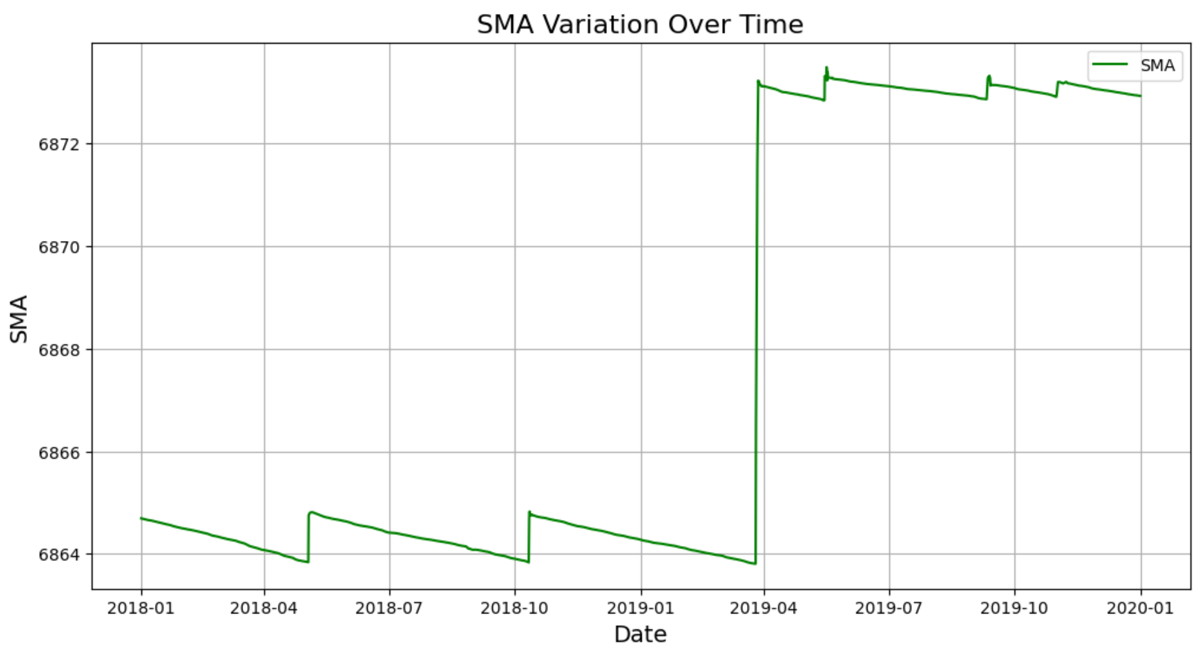
DATASET DESCRIPTION

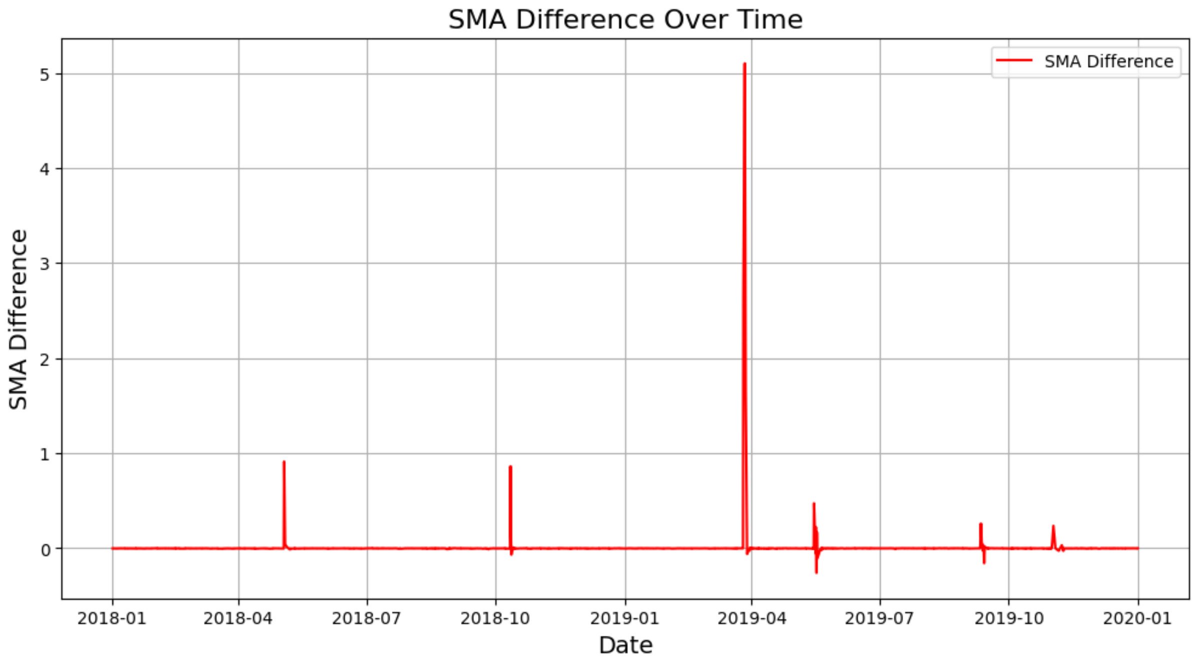
The dataset consists of historical orbital data with two key columns: **Datetime** and **SMA**. The Datetime column records the precise timestamp of each observation, capturing both date and time details. The SMA (semi-major axis) column provides measurements of the satellite's semi-major axis at corresponding timestamps. This data is essential for analyzing variations in orbital parameters and detecting maneuvers based on changes in the SMA over time.

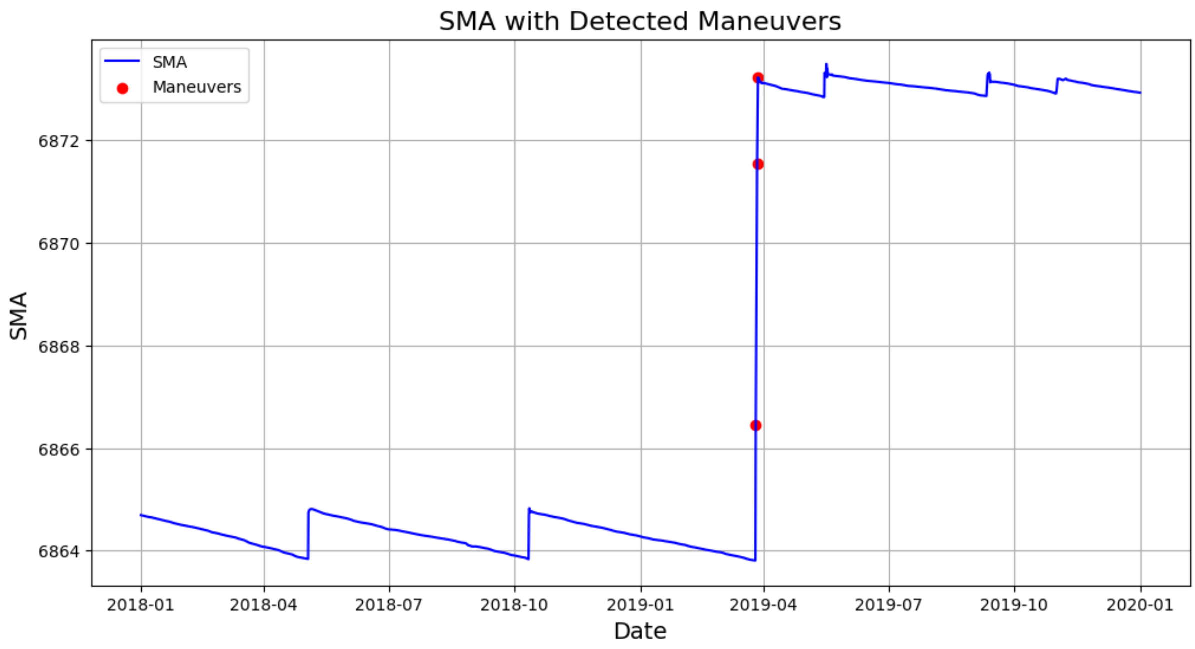
DATA PRE-PROCESSING

- **Checked for Null and Missing Values**: The dataset was inspected for any null or missing values. It was confirmed that there were no missing values in any of the columns.
- **Calculated SMA_diff**: The difference in SMA values between consecutive observations was computed and stored in the SMA_diff column.
- **Added Maneuver Detection Column**: A new column, Maneuver, was introduced to indicate whether a maneuver had occurred based on a predefined threshold. This column helps in identifying significant changes in the orbital parameters.
- **Calculated Days_Since_Last_Maneuver**: For each entry, the number of days since the last detected maneuver was calculated. This information is crucial for tracking the time intervals between maneuvers.
- **Separated Datetime Column**: The original Datetime column was split into separate Date and Time columns for easier analysis and manipulation of the dataset.
- **Expanded Dataset Columns**: The dataset was transformed from the initial two columns to a more comprehensive set, including **SMA**, **SMA_diff**, **Maneuver**, **Date**, **Time**, and **Days_Since_Last_Maneuver**. This enhanced column set provides a detailed view of the satellite's orbital parameters and maneuver timings.

GAINED INSIGHTS







- **SMA Variation Over Time**: This plot displays the trend of SMA values throughout the dataset period. It helps to visualize how the orbital parameter fluctuates over time.
- **SMA Difference Over Time**: This graph shows the changes in SMA between consecutive data points. It highlights periods of rapid change that could indicate maneuvers or anomalies.
- **SMA with Detected Maneuvers**: This plot overlays SMA values with markers indicating detected maneuvers. It illustrates how identified maneuvers align with changes in the SMA values.

Heuristic Approach

1. Maneuver Detection

- **Last SMA Value**: The latest SMA value in the dataset was identified.
- **Threshold Definition**: A threshold of ±1 from the last SMA value was set to determine significant deviations.
- **Detection Logic**: If the user-provided SMA value falls outside this range, a maneuver is detected; otherwise, no maneuver is detected.

2. Days Left for Next Maneuver

- **Threshold for Maneuver**: A maneuver threshold of 449 days was defined to assess time intervals.
- **Date Validation**: Ensured user-provided dates are within the dataset's range.
- **Calculation**: Computed the number of days since the last maneuver and the days remaining until the next maneuver based on the input date.

Conclusion

- **Heuristic Approach**: Given the limited data, a heuristic method was chosen over machine learning for maneuver detection.
- **Data Handling**: Data preprocessing steps included calculating SMA differences, maneuver detection, and handling date-based metrics.
- **Utility**: The developed methods effectively provide insights into maneuver occurrences and time intervals based on user inputs.