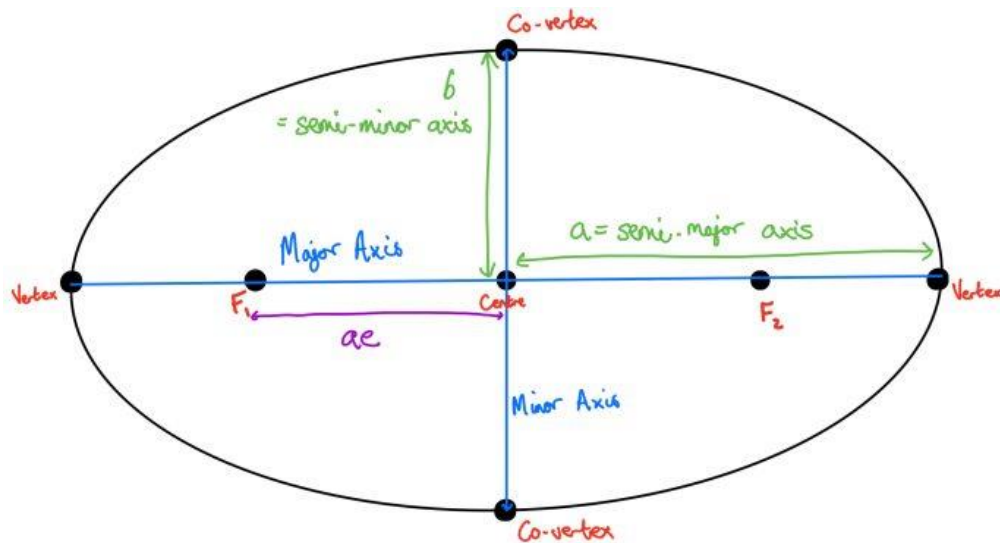


Detecting Satellite Maneuvers

What is Semi Major Axis and How we can use it to detect satellite maneuvers?

The semi-major axis represents the satellite's average distance from the whatever body it's orbiting. In this case we are assuming its orbiting Earth. The semi-major axis of a satellite's orbit can be used to detect maneuvers by observing changes in its orbital parameters over time. When a satellite performs a maneuver, such as a thrust or trajectory adjustment, its velocity and position change, which directly affects its orbit, including the semi-major axis.

We can calculate SMA using Kepler's Third law. But for this assignment we already have SMA in the data.



In this Notebook we are going to build a model which detect maneuvers using two techniques-

- Heuristic- Observing Change in Speed and SMA
- Random Forest ML Model

References-

- https://www.researchgate.net/publication/362619675_Satellite_Manuever_Detection_Using_Machine_Learning_and_Neural_Network_Methods
- <https://space.stackexchange.com/questions/44825/get-dates-when-a-satellite-has-performed-maneuver-from-historical-tle-data-pyth>
- <https://amostech.com/TechnicalPapers/2022/Machine-Learning-for-SSA-Applications/Perovich.pdf>
- Open AI, Perplexity

About Data- The dataset contains two columns:

- Datetime - timestamps of satellite events.
- SMA (Semi-Major Axis) - the orbit's characteristic dimension in kilometers.

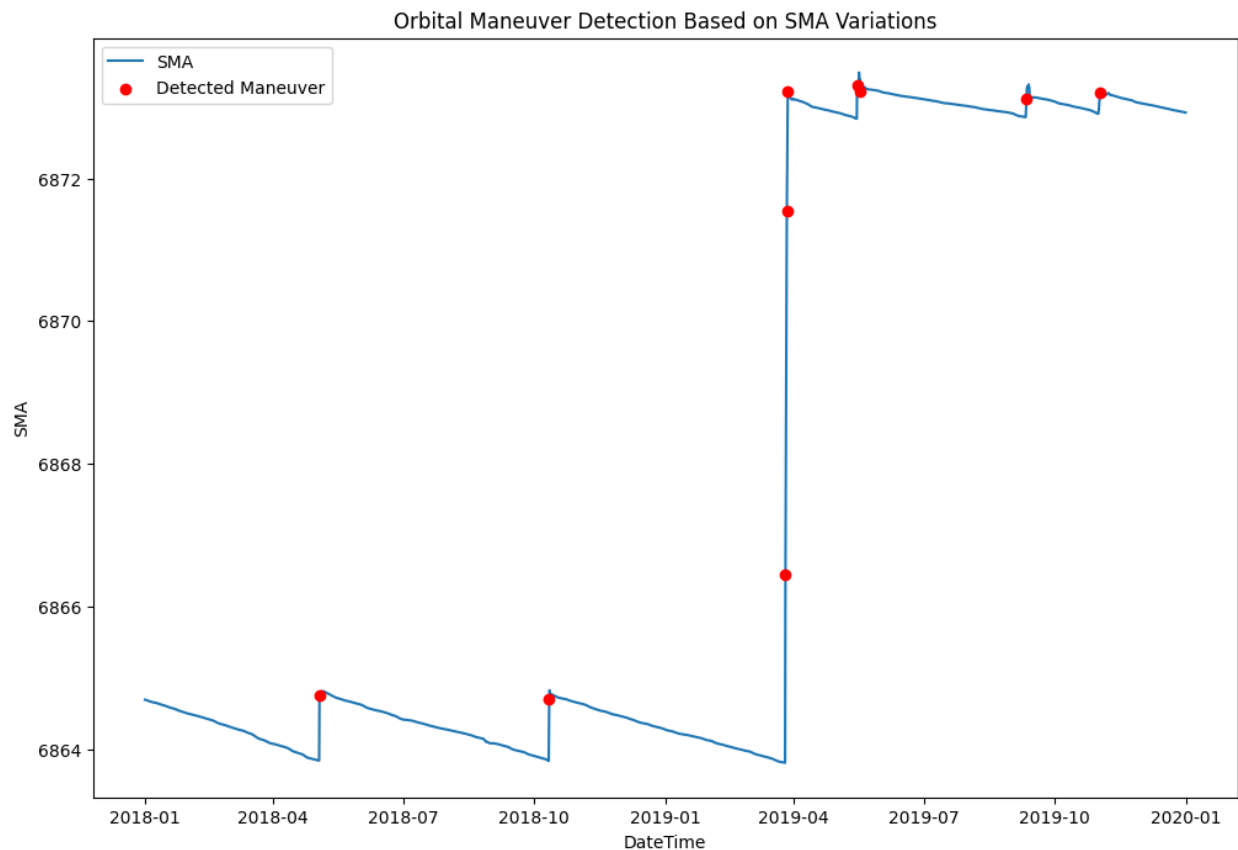
Heuristic Method (SMA & Speed Anomaly)

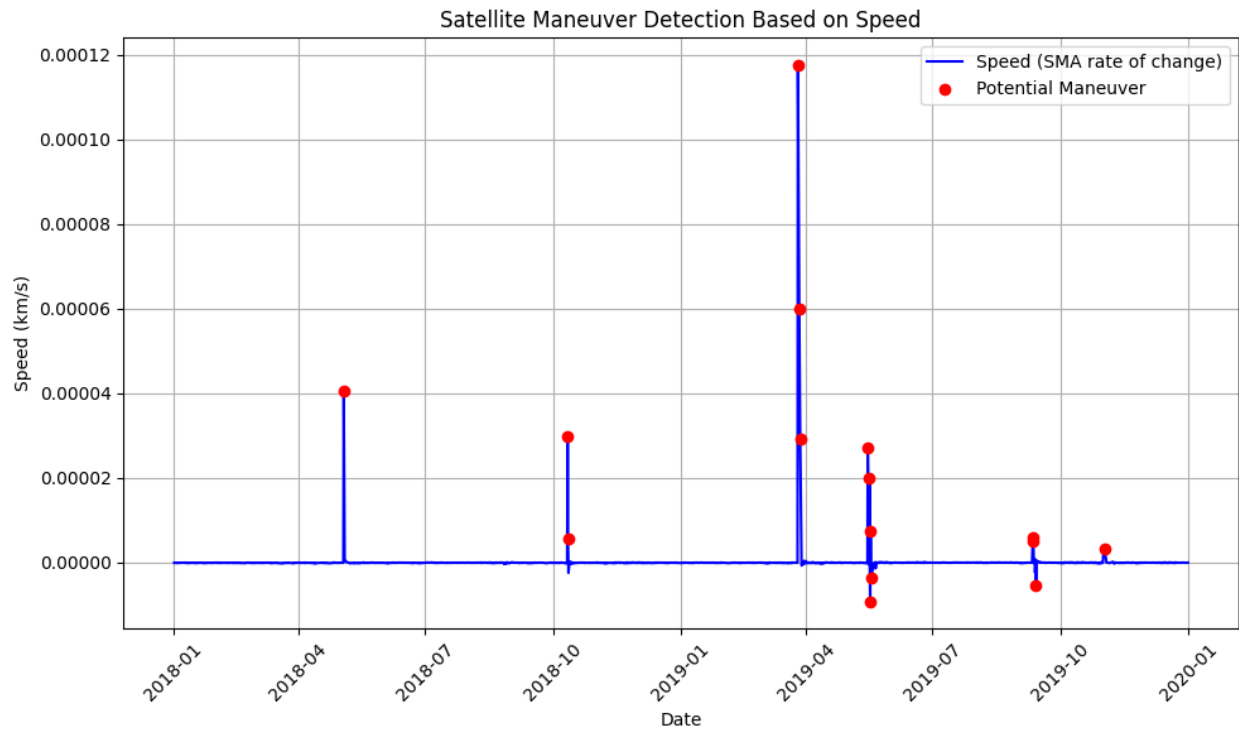
In Heuristic approach we will analyze anomalies in orbital parameters SMA, velocity of satellite data.

1. **Speed Changes:** By observing how quickly the semi-major axis changes over time, we can detect shifts that suggest a burn or ejection event. Compute the speed by calculating the difference in distance (SMA) over time. We will try using different Standard deviation threshold to see which give better result.

$$\text{Speed} = \Delta \text{SMA} / \Delta \text{time}$$

2. **SMA Thresholds:** Using standard deviation or fixed thresholds can flag potential maneuvers. e.g., one standard deviation above will flag the maneuvers.





Machine Learning Method (Random Forest)

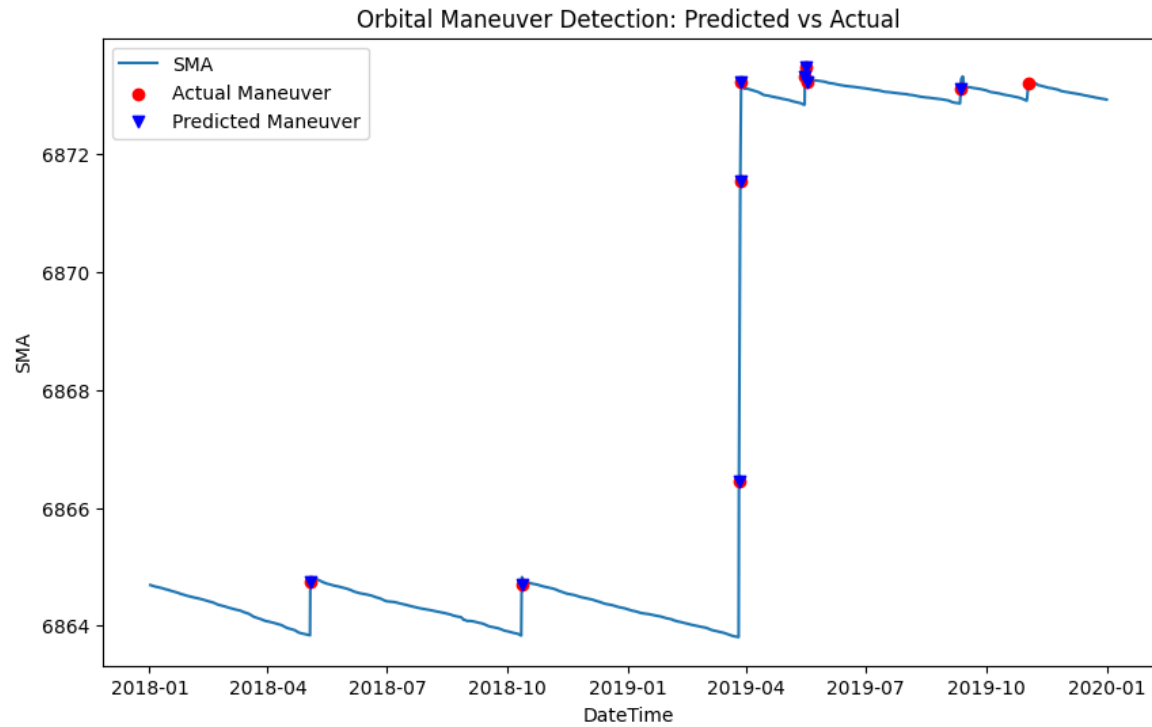
ML model would use labeled data to train a model that learns to detect maneuvers based on the SMA patterns. But we don't have labelled dataset. A threshold (Deviation from Std) is used to label whether a point represents a maneuver (1) or not (0).

The model is trained on 70% of the data and tested on 30%. **But there will be overfitting due to small number of maneuvers in the data. It makes data imbalance.**

In the below image- Blue Triangle shows the predicted maneuvers and Red circle represent Actual Maneuvers. This model is giving accuracy of 99% due to overfitting of the data. We need large balanced dataset which contains actual maneuvers to remove overfitting.

And the table below that graph shows predicted maneuvers dates by different methods.

Python Code- https://github.com/aarsh121/Financial-Analysis-using-Python/blob/main/Satellite_Maneuvers.ipynb



	ML Model Dates	SMA Dates	Speed Dates
384	2018-05-03	2018-05-03	2018-05-03
871	2018-10-11	2018-10-11	2018-10-11
872	NaN	NaN	2018-10-11
1421	2019-03-26	2019-03-26	2019-03-26
1422	2019-03-27	2019-03-27	2019-03-27
1423	2019-03-27	2019-03-27	2019-03-27
1583	2019-05-15	2019-05-15	2019-05-15
1585	2019-05-16	NaN	2019-05-16
1587	2019-05-17	2019-05-17	2019-05-17
1588	NaN	NaN	2019-05-17
1589	NaN	NaN	2019-05-17
1944	2019-09-11	2019-09-11	2019-09-11
1945	NaN	NaN	2019-09-11
1951	NaN	NaN	2019-09-13
2120	2019-11-01	NaN	2019-11-01