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Integrating Machine Learning algorithms into Orbit Determination: The AI4POD Framework

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Abstract
Accurate orbit determination is essential for mission planning, execution, and maintaining space situational awareness, ensuring the success of space missions and the effective management of space traffic. This is particularly critical for deep space missions, where precise navigation and trajectory estimation are vital for conducting scientific research. While traditional numerical methods for prediction and determination have proven to be robust and accurate, they can be limited when faced with dynamic parameters or unmodeled forces. Integrating machine learning (ML) algorithms offers a way to enhance accuracy, especially for models requiring complex simulations.
Peng H. and Bai, X. [1] show that a Support Vector Machine (SVM) is a promising candidate to improve the accuracy of orbit prediction, especially for Earth satellites. In this paper, we extend this approach to the Rosetta mission, enhancing its orbit prediction. We introduce AI4POD (Artificial Intelligence for Precise Orbit Determination), a software package that combines classical orbit determination methods with modern ML techniques. AI4POD includes several tools for conducting orbit predictions and determinations and features a comprehensive force model that incorporates various forces, such as spherical harmonics for gravity field modeling, third-body perturbations, solar radiation pressure, atmospheric drag, and more.
We simulate the orbit of the Rosetta spacecraft around the comet 67P/Churyumov-Gerasimenko and compare it to real mission data [2, 3]. Orbital parameters can be determined using Weighted Least Squares (WLS) estimation or a Kalman filter. The SVM algorithm is implemented alongside other tools to learn the generalized error of the simulation, thereby improving the accuracy of orbit prediction.

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