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SATELLITE CHARACTERIZATION USING THE THEORY OF FUNCTIONAL CONNECTIONS AND NELDER-MEAD ALGORITHM

Abstract

The improvement of orbit propagation algorithms depends on the quality of its mathematical models. A good prediction of the orbit of a satellite depends, among others, on accurate information of its properties, like the combination of its: cross area, total mass, shape, distribution of mass, reflectivity, etc. This information is often not available, for instance, when it is related to space debris. The satellite characterization is a challenge that can be met by thinking about observation data (position, velocity, light curves, etc.) using optimization methods. In this work, it is proposed two state-of-the-art optimization procedures to determine the parameters associated with the dynamics of a satellite, one based on the Theory of Functional Connections (TFC) and another on the Nelder-Mead algorithm. Constrained ordinary differential equations (ODE) can be numerically solved using the TFC with high accuracy and low computation time. TFC can be used to reduce the space of solutions to the one that satisfies the constraints. This is done by creating and inserting the "constrained expression" into the original ODE, which will have all the constraints of the problem analytically embedded. It is proposed in this work the use of the observational data as the constraints through TFC. Thus, any possible solution coming from the subsequent optimization procedure will analytically satisfy the observational data. After that, the nonlinear least squares method is used to improve the mathematical models which are used to describe the motion of a satellite. A second method is also proposed in this research, which takes the advantage of the Nealder-Mead algorithm as a Machine Learning alternative to the optimization problem. This algorithm is a heuristic and pattern search method, which can obtain the parameters that satisfy the constraints given by the observation data with higher accuracy at each step. Both methods proposed in this work have never been applied to the satellite characterization problem. Thus, the new methods presented in this work can be useful to obtain the parameters of the satellite from the available observational data in a timely manner, with good accuracy to be applied to space debris characterization, and with sufficient numerical convergence to be used as independent methods. The procedures developed in this work are being coded to be applied to space debris characterization through the data obtained from the Pampilhosa da Serra Space Observatory (PASO).