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ASSESSING INITIAL ORBIT DETERMINATION METHODS FOR SPACE DEBRIS TRACKING FROM A SPACECRAFT ORBITING THE EARTH

Abstract

This presentation focuses on the theoretical preparation of space debris observation missions from a satellite orbiting the Earth.

In particular for uncatalogued objects, the exploitation of observations requires the use of initial orbit determination (IOD) methods, from a very small number of observations. In case of debris resulting from explosions, or of satellites present in observations but whose orbital elements are not publicly disseminated, orbit determination cannot be based on traditional methods such as least squares or Kalman filter, which assume a satisfactory a priori knowledge of the orbital elements.

The best-known methods are the Laplace and Gauss methods : from three observations, these methods compute the distance between the local observer and the object, using an interpolation of the vectors' derivatives (Laplace) or for each of the three observations, ensuring the coplanarity of the Keplerian orbit (Gauss). However, they suffer from numerical instabilities, making them often impractical. This is especially true for Laplace's method.

Other methods are more modern approaches to the problem, taking for instance advantage of an efficient, universal Lambert solver to compute the third position (Gooding), or solving the sector-triangle ratios between points to vary the first and last observer-satellite distances (Herget). We also consider exploring an extension of those IOD methods, with either newer techniques or enhancements, such as Izzo's implementation of Gooding's algorithm or the use of genetic algorithms (Hinagawa et al, 2014 ; Ansalone Curti, 2013).

A key part of our evaluation is to consider the robustness of each method to the observer's position noise. Unlike ground stations, space-based platforms are not as accurately located. This additional layer of uncertainty challenges the application of IOD techniques and underscores the importance of adopting robust algorithms. This is particularly true for observations of objects far from Earth and for very short observation arcs.

This presentation therefore aims to summarize and provide a comprehensive evaluation of various IOD methods' performances, according to the geometric configurations of the observations, and to quantify the corresponding error balance. This assessment takes into account not only the errors inherent in each

of these methods, but also the uncertainty in the knowledge of the trajectory of the observing satellite. Numerous tests are carried out to quantify these performances, on the basis of SLR precise orbits seen as the reference.