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DETECTION OF SATELLITE MANOEUVRES USING NON-LINEAR KALMAN FILTERS ON PASSIVE-OPTICAL MEASUREMENTS

Abstract

As part of an ongoing effort to build and maintain a data base for Space Situational Awareness, we have been developing an algorithm, which employs a non-linear Kalman Filter to detect satellite manoeuvres. This methodology works directly on the astrometric angle measurements derived from passive-optical telescope observations without the need to run an orbit determination step first. In this study, we analyze the performance of this algorithm, and use it to detect and characterize several manoeuvres performed by a number of satellites.

In order to assess the capabilities and limitations of this method, we first created a large set of synthetic observations based on precisely known orbits of Galileo satellites. With that in hand, we study the effects of varying different properties of the data, such as the noise level, the number and density of the observations, and, most importantly, the manoeuvre type and magnitude.

As a second step, we apply the manoeuvre detection algorithm to real multi-site astrometric observations of several satellites obtained with optical telescopes of the SMARTnet sensor network, including observations during the launch and early orbit phase of a satellite. Like our simulated observations, our real-world data set comprises different observation numbers and densities for different satellites, as well as manoeuvres of very different magnitudes. In some cases, the true manoeuvre details were known to us, so we could verify our findings.

We detect a number of manoeuvres in our observations, and in many cases, we also determine the manoeuvre epochs and Δ-v components. This is done by means of a conjunction analysis, during which we forward- and backward-propagate the state estimates at the epochs of the observations bracketing a suspected manoeuvre. We then calculate the collision probability between these two orbital tracks and determine the manoeuvre epoch and Δ-v components at the time of maximum collision probability.