Feature-based estimation of the dynamic state of uncooperative space objects

Gabriele Biondi[1], Stefano Mauro[1], Tharek Mohtar[1], Stefano Pastorelli[1], Massimo Sorli[1]
[1]*Department of Mechanical and Aerospace Engineering, Politecnico di Torino, Torino, Italy*
E-mail: gabriele.biondi@polito.it, stefano.mauro@polito.it, tharek.mohtar@polito.it, stefano.pastorelli@polito.it, massimo.sorli@polito.it

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A set of methods and algorithms were developed for the complete estimation of the dynamics of uncontrolled space objects such as mission related debris, spacecraft fragments or tiny asteroids.
The prediction of the motion and of the mass distribution of a space debris becomes fundamental in order to capture and subsequently conduct in a controlled way the debris toward safe graveyard orbits or toward the Earth. The total number of Earth orbiting space debris is significantly increasing [1] together with the risk of unexpected collisions with active satellites and of uncontrolled reentries into the Earth's atmosphere.
The only required data consist of noisy Euclidean coordinates of few features of the body which is assumed as rigid.
The methods were tested considering the simulated motion of a benchmark spacecraft on a virtual environment. A finite set of markers were attached on the benchmark spacecraft and their coordinates were calculated consistently with the simulated motion. Then the effective visibility of these features was considered in relation of their position with respect to a stereovision observer placed on a simulated chaser spacecraft.
The localization of the center of mass of the object was performed exploiting a 3D kinematic registration algorithm [2]. The recognition of two different instantaneous axes of rotation of the body in a very short time interval leads to the identification of the center of mass by finding some "pseudo-intersection" of these axes.
At the same time, the coarse knowledge of the position of some points belonging to a rigid body is useful to evaluate corrupted signals, such as unit quaternions, which represents the attitude of the body itself. The recovery of these corrupted signals was performed adapting compressed sensing techniques for image processing [3]. A linear Kalman filter is then used to estimate the quaternions derivative in order to evaluate the absolute angular rate of the body.
Finally, to complete the estimation of the dynamic state, the normalized principal inertia tensor of the body was evaluated via an unscented Kalman filter [4]. The implemented unscented Kalman filter exploits the estimated angular rate measures and improves at the same time the quality of these same estimates.

References

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