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ANGULAR RATE DETERMINATION USING STAR SENSORS AND NOVEL ALGORITHMS BASED ON GEOMETRICAL INVESTIGATIONS

Abstract

Angular rate determination represents an essential task for the navigation system of space platform. Usually, the evaluation of the rate is demanded to gyroscopes, but new mission concepts have been recently proposed involving the usage of star sensors. Indeed, star sensors already represent the best technology concerning attitude determination, and their usage can be extended to rate determination. This new paradigm can help the on-board navigation system and eventually lead to avoid using gyroscopes and simplify the overall satellite hardware architecture.

In this paper, a geometrical investigation of the star sensor image is performed under dynamic conditions. When the satellite experiences a non-negligible angular velocity, stars inside the sensor field of view leave a trace which is no more a circular spot but an elongated streak. Indeed, it is shown that this streak is a portion of a conic section which features depend on the angles between the instantaneous rotation axis, the sensor boresight and the star direction. It is demonstrated that the intersection point of the rotation axis with the focal plane lies on the line passing through the conic section foci and the geometrical center of the detector. A mathematical model to simulate the generation of the conic section is developed and it is used to discuss theoretical investigations involving osculating circles near the pericenter points, properties of the conic sections, and relationships between the previous two points and the angular velocity vector.

The discussed geometrical properties can be exploited to develop new methods for the evaluation of the angular rate in dynamical conditions (up to five degree per second) without needing any attitude information. In the frame of this research, the angular velocity estimation is performed by means of the chord method, which is based on the computation of the normals to the streaks and their intersections. A high-fidelity simulator is used to generate synthetic images with the star streaks and all the fundamental noise sources due to electronics and space environment. Preliminary results show that the angular velocity can be estimated with relative rate errors lower than 1