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ASTROMETRIC AND PHOTOMETRIC DATA FUSION FOR INACTIVE SPACE OBJECT FEATURE ESTIMATION

Abstract

Space Situational Awareness (SSA) is concerned with collecting and maintaining knowledge of all objects orbiting the Earth. A global network of radar and optical sensors collects the necessary data for coarse space-object-catalog development and maintenance. Some powerful ground-based telescopes can resolve large Space Objects (SOs) in Low Earth Orbit (LEO) such as the Hubble Space Telescope and the International Space Station to high detail. Unfortunately most objects are too small and/or too distant to lend themselves to ground-based resolved imaging; such classes of objects are labeled as unresolved objects. In particular, SOs in geosynchronous orbits and "micro" and "nano" satellites are too small to be resolved using ground-based optical telescopes and fall under the class of unresolved objects.

Although the amount of light collected from these objects is small, optical observations may still be gathered to support orbit determination and SSA efforts. These observations cannot directly resolve the shape of the SO; however, by analyzing the time history of the measured brightness (light curves), one can infer physical properties. Such properties include the object's physical parameters such as surface characteristics, shape, and attitude dynamics. Past work has shown that SO shape information can be extracted from these data. This work examines the exploitation of the inferred angular velocity and attitude profile of a SO from light curve data to recover the mass-specific inertia matrix. The moments of inertia and mass distribution are tightly coupled with the rotational dynamics of an object, though the observability of these quantities from attitude profiles may be low for particular angular velocities. Unless the mass of the SO is known, one may only be able to observe the mass-specific matrix rather than the full inertia matrix. In this work an estimation strategy is developed to quantify the mass-specific inertia matrix while making use of inertia matrix properties such as positive definiteness and symmetry. The observability of these quantities is examined using analytical formalisms and information-theoretic concepts such as mutual information. Degenerate cases are identified. Supporting numerical simulations are provided for different SO angular velocity and attitude profiles to highlight the performance of the approach and observability issues.