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Title

Characterization of space objects' attitude motion using Lomb-Scargle Periodogram

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Abstract

The characterization of Earth-orbiting objects is an increasingly relevant task in Space Domain Awareness (SDA). It consists in retrieving information about space objects' properties, i.e., attitude motion, material and shape, to be combined with orbital state data, to achieve a more in-depth knowledge of the Earth's resident space objects (RSOs). Photometric information, such as light curves, can be used to extract both dynamical and physical properties of space objects. Light curves can be obtained from the light reflection of objects illuminated by the Sun and they measure the brightness of objects over time. Indeed, the reflected brightness is a function not only of the object properties, but also of the observation geometry which is determined by the reciprocal positions of object, observer and Sun. Furthermore, being produced by a measurement process, light curves suffer noise issues, mainly due to light contamination from other objects, atmospheric effects and detection limitations of the optical sensors.

To sum up, light curves can contain useful information to properly characterize space objects, although their inversion represents a non-trivial operation. Several methods exist to deal with light curve inversion problem, aiming at reconstructing shape or attitude motion of RSOs. Some methods use data fusion techniques, e.g., combining light curves and observation angles data by employing Unscented Kalman Filters and multi-model adaptive estimation approach to determine the most probable shape. Other methods, instead, perform direct analysis of the frequency spectra obtained from the light curves, e.g., using Fast Fourier Transform, Epoch Folding or Periodogram analysis, to extract attitude information, such as spin periods of space debris objects. Furthermore, multi-objective optimization based on genetic algorithms is also used to minimize the residuals between real and simulated light curves in order to determine the attitude motion.

In this framework, this paper presents an architecture for characterization and classification of the attitude motion of the space objects. The proposed architecture exploits the Lomb-Scargle Periodogram algorithm to retrieve frequency spectra from light curve measurements, and then performs the classification by analyzing the characteristics of the spectra, e.g. peak frequencies or their periodicity. Performance of the method are tested using light curves generated synthetically by means of a light curve simulator, which is included in the proposed architecture and considers several geometric models and materials to simulate object's properties. Performance dependance on observation geometry as well as multi-temporal and multi-sensor measurements is also assessed, by simulating light curves in various observation scenarios. Finally, the method is applied to real light curves extracted from a publicly available light curve database.