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Mechanical and Aerospace Engineering Department
University of Texas at Arlington

SHAPE MODELING, ATTITUDE ESTIMATION, AND CLASSIFICATION OF ARTIFICIAL RESIDENT SPACE OBJECTS (RSO) USING PHOTOMETRIC LIGHT CURVES

By

KATIYAYNI BALACHANDRAN

Dissertation Advisor: Dr. Kamesh Subbarao

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Abstract

Light curve inversion (LCI) has proven valuable in using photometric measurements to optimize various physical parameters of a resident space object (RSO) such as rotational period about its own spin axis, pole orientation and others. Other characteristics such as shape and size are dependent on the surface brightness. To accurately determine size, shape, spin rate, or attitude information of an unresolved resident space object, photometry is required to capture the relatively rapid changes in brightness that these objects can exhibit. LCI has been developed significantly for asteroids, although not fool-proof for artificial RSOs. Satellites and space debris, unlike asteroids, are dynamic in lighting and viewing geometry because they are closer to Earth. Additionally, while asteroids are roughly round, smooth, and have stable rotations, the opposite is true of man-made space objects, which often have sharp edges and flat surfaces that produce distinct specular glints. The minimal studies performed for satellites utilize *a priori* information on attitude and a simplified geometric model such as a cuboid. The objective is to determine the sidereal rotation period and shape of the RSO and subsequently, classify the object using these parameters.

Optical measurements for space object tracking are sensitive to shape, attitude, angular velocity, and surface parameters. Current state-of-the-art in RSO characterization relies heavily on nonlinear estimation theory which is computationally expensive. A data-driven approach for improved accuracy with a large volume of objects employs the use of deep neural networks. Given an unresolved object's light curve, in low earth orbit (LEO), we can characterize it by shape and spin rate using a Hidden Markov model (HMM) and Long Short-term Memory Recurrent neural network (LSTM RNN). The tumbling rates are computed using the Lomb-scargle periodogram, which performs more accurately as opposed to other signal processing methods, and the synthetic light curves are generated using the Lebedev quadrature. This integrated model has been developed to identify tumbling and stabilized objects by testing for aliasing, periodicity, and feature extraction.

The application of photometric light curves has been extended to model Triton's atmosphere. To quantify the distortion required to reproduce the measured light curve (stellar occultation), a global model of the atmosphere of varying ellipticity can be constructed and fit using least-squares method. We can use the operations concept of a space probe releasing hundreds of small satellites into orbit around Triton in delayed succession to improve data collection capability and provide redundancy due to power constraints. The simulated data (with additional astrometric data of Triton) can be 3D mapped to generate the atmospheric model and validate predictions of Triton's expanding atmosphere due to thermal properties of the surface and increase in pressure.