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HYPERSPECTRAL CLASSIFICATION OF SPACE OBJECTS

Abstract

This paper will demonstrate the use of hyperspectral sensors to characterise space objects from single pixel images. In the general case this is an under-determined problem, however the range of space objects that is likely to be observed is constrained to certain classes of objects. For example, satellites generally have surface consisting of aluminium or solar panels all of which have distinct spectral signatures. A classification system is proposed to quickly identify and group space objects according to their spectral signature. The key idea is to spectrally decompose the light emitted and reflected by space objects to better reconstruct their surface composition and attitude motion. The motion is derived from a spectral light curve analysis. Since different materials absorb and reflect light differently at different wavelengths, by measuring the decomposed lightcurve one can identify the composition of the surface of a space object. By tracking periodic changes in the spectrum, with a given material composition being associated to particular axes in the body, one can also estimate the attitude motion. Lightcurve analysis without any spectral decomposition is often used to reconstruct the motion of asteroids and has been proposed for space debris as well. In the specific case of space objects around the Earth if the orbit is sufficiently known through other means and one can decompose the light coming from an observable object, what remains is the light intensity per wavelength, which varies in time due to rotation. This the paper first will present a high-fidelity simulation model of the measured decomposed lightcurves from arbitrary objects, followed by a classification algorithm which associates types of objects to spectral classes that are representative of their surface composition. Two methods for attitude motion estimation are then introduced. Both methods exploit the added knowledge that comes from the spectral light curves. One method is based on traditional least-square filtering, the other utilises a Generative Adversarial Network (GAN) to match the spectral light curves to possible attitude motions. The model and simulations were validated against laboratory experiments. Both ground-based and space-based telescopes were simulated, including the effects of wavelength- and elevation- dependent atmospheric attenuation for the former.