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PHOTOMETRIC AND ATMOSPHERIC CALIBRATION OF OPTICAL SENSORS FOR SPACE DEBRIS CHARACTERIZATION

Abstract

Commercial-off-the-shelf (COTS) optical sensors have proven to be affordable, yet feasible data sources, which can feed the cataloguing and light-curve-based characterization activities undergone by modern Space Surveillance and Tracking (SST) providers. These are paramount toward space debris awareness and mitigation. For their data to be exploited efficiently, these sensors need to be properly calibrated, both against their own specifications and the observation conditions.

In particular, regarding photometric calibration and the generation of light curves, the apparent magnitude of an object of interest is often obtained relative to other stars that appear in the background, for which it is known. However, some observation scenarios do not yield frames where the background star field is dense enough for relative photometry to be performed – e.g. observation of a LEO object under considerable windowing does not capture enough reference stars. Furthermore, the comparison of light curves taken on different days or from different locations is more informative if the photometric artifacts in each observation are known or can be estimated.

This paper presents an alternative method to simultaneously estimate the overall transmissivity of the telescope, as well as the atmospheric parameters that drive the scattering of light. It applies least squares techniques on frames of known star fields, which have been taken throughout an entire observation night. Two alternative estimation architectures are compared, in combination with three data correlation hypothesis. Furthermore, this paper includes a magnitude correction algorithm to compensate for the fact that reference star catalogues may use a different transmissivity curve than that of the sensor being calibrated, which has been specifically developed for the application at hand.

The proposed photometric calibration algorithm is demonstrated in this paper by calibrating the 30cm-aperture ART, located in Extremadura, Spain. Results show that the calibration residuals often lie within a symmetric distribution that fits a T-Student with low degrees of freedom, with reasonable agreement with ART's specifications. Atmospheric attenuation can vary significantly across different nights, or even over several hours during the same night.

This new method opens the door to a per-night, systematic calibration of the atmospheric conditions at the observer location, which synthesize key information on the observation conditions, may indicate the presence of artifacts or other aberrations in the sensor, and can be used to efficiently remove atmospheric and instrumental biases to observed light curves, without having to resort to per-image differential photometry.