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RELATIVE ORBIT ESTIMATION COMBINING BEARING AND PHOTOMETRIC MEASUREMENTS

Abstract

Relative orbit estimation is a important technique in on-orbit servicing missions not to enlarge the risk of collision. At a far range, the observations are obtained by an optical camera and are unresolved images of the target object, which provide two-dimensional position on a camera image. This observation is also described as two bearing angles, i.e., azimuth and elevation angles from the service satellite to the target. The relative orbit estimation with bearing angles is known as angles-only navigation and has been intensively studied. The difficulty of angles-only navigation stems from the observability of the relative distance. That is, the relative distance norm between the service satellite and the target is weakly observable. Although this difficulty can be avoided by implementing known maneuvers or considering nonlinear motion caused by perturbations, they consume extra fuels or provide a slight improvement of the observability. To enhance the observability, this study fuses the light intensity of the unresolved image, called light curves, with bearing angle observations. The light curves depend on the relative distance between the service satellite and the target, and the data fusion of light curves can compensate for the weakly observability of the relative distance. Light curves include information on not only the target orbit but also the attitude, shape, and optical properties of the target, which are formulated with a bidirectional reflectance distribution function (BRDF). This study uses the Ashikhmin–Shirley model to describe the light curves of the target, because this model can express both isotropic and anisotropic reflection. The BRDF is a highly-nonlinear function of the target state, and the unscented Kalman filter is employed to estimate the relative state of the target. Numerical simulations consider two types of objects: a flat plate and a box-wing satellite, which verify the proposed relative orbit estimation method compared to a conventional angles-only method. Furthermore, two optical properties, i.e., isotropic reflection and anisotropic one of the Ashikhmin–Shirley model, are examined. The simulation results show that the convergence rate of the relative distance is significantly improved by the light curve observations. Fisher information as a quantitative metric is also compared with the conventional method.