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MULTI-SENSOR SPACECRAFT ORBIT DETERMINATION THROUGH A COMBINATION OF RADIOMETRIC AND IMAGING DATA

Abstract

The future space exploration missions will require autonomous probes to conduct scientific investigations across remote areas in the Solar System. To enhance the navigation capabilities of deep-space probes, novel data-fusion approaches are designed to support real-time operations through the combination of traditional radio tracking data with auxiliary measurements provided by other onboard instruments, including optical cameras. Imaging data can be acquired and processed by the onboard spacecraft navigation system independently from the intervention of ground operators, making them suitable to autonomous orbit determination through the detection and tracking of surface landmarks. This approach is fundamental when radio tracking data are not available, and the spacecraft is facing highly risky operations. Cutting-edge deep learning architectures that are robust to the illumination conditions and image spatial resolution can be used to extract morphologic surface structures (*e.g.*, craters) from the acquired imaging data. Computer vision techniques (*e.g.*, ray tracing) can then be used to generate digitally-rendered images that are consistent with the estimated observation geometry and the planet's topography. The 2D sample/line displacements of the extracted features in the observed and synthetic images can provide orbital corrections in the along- and cross-track directions that are complementary to radio tracking data, leading to improved orbit determination accuracies. By carrying out thorough numerical simulations based on realistic mission scenarios (*e.g.*, Lunar Reconnaissance Orbiter, Europa-Clipper), we investigate the benefits of the data-combination approach to enhance the spacecraft orbit determination. High-resolution topography data from global and local digital terrain models (DEM) of the Moon will be processed to generate the synthetic data for the optical navigation, and an up-to-date lunar crater catalogue will be employed to aid in the matching of the observed landmarks. The image-based observations will then be combined with preprocessed radio tracking data by accounting for measurements accuracies and orbit geometries (*e.g.*, face-on, edge-on) to better assess the performances of the proposed software based on a multi-sensor approach.