Paper ID: 66812
oral
student

IAF SPACE EXPLORATION SYMPOSIUM (A3)
Small Bodies Missions and Technologies (Part 2) (4B)

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MULTISPECTRAL IMAGING SENSORS FOR ASTEROIDS RELATIVE NAVIGATION

Abstract

Relative navigation techniques in proximity of asteroids mainly rely on optical measurements. However, visible band poses several constraints to the spacecraft trajectories and operations, since an adequate surface illumination is needed to get fruitful measurements. Nevertheless, other sensors might be available on board, working in different spectral bands which could be exploited for navigation purposes.

An innovative navigation architecture which exploits both Visible (VIS) and Thermal Infrared (TIR) imaging is here presented.

The proposed architecture combines image processing techniques for pose estimation - applied to the VIS and TIR raw data - with filtering methods for sensor fusion. An Extended Kalman Filter (EKF) fuses the image processing outputs with star tracker, gyroscope and altimeter measurements to refine the pose and reconstruct the asteroid's spin state.

The algorithm is tested on synthetic images: VIS images are generated by means of classical rendering techniques, while TIR images are obtained from the the asteroid surface thermal behaviour modeling. An uncooled microbolometer sensor is modeled in the TIR images generation process. Microbolometer sensors present numerous advantages, such as the possibility to operate without cooling system; thus, having reduced dimensions, this technology is a promising option for deep-space cubesats as well. For generating TIR images, first, rendering techniques are employed and then TIR images are processed to obtain a more representative appearance of the target asteroid. In particular, to match the expected microbolometer physical response - proportional to the radiation power absorbed by the detector pixels - masks are exploited.

The paper critically compares improvements obtained with the proposed navigation architecture against the vision-based only approach. The TIR images generation process is validated with real thermal images from the Hayabusa 2 mission. Although TIR images offer reduced resolution with respect to VIS data, the adopted approach highlights that the VIS-TIR measurements fusion leads to improvements in the order of 32%, 30% and 18% in localization, attitude and spin state estimation respectively. The presented approach for relative navigation based on VIS-TIR measurements is tested for an asteroid target, but it represents a promising option for a wide set of applications, including other types of targets.