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SMALL SATELLITE ATTITUDE VERIFICATION USING MULTISPECTRAL IMAGERY OF MOON AND EARTH HORIZON CONSTELLATION

Abstract

Accurate attitude determination of a spacecraft is crucial for applications such as Earth observation and scientific missions, both increasingly often realised with small satellites. In the space sector, a wide range of attitude determination sensor types is available. However, to validate the measured attitude, a sensor-independent attitude determination method is necessary. Nowadays, Earth observation payloads, including visible (VIS) and infrared (IR) cameras, are commonly integrated into small satellite systems. Traditionally, verifying a spacecraft's attitude involves comparing it to geo-referenced imagery of Earth's surface, a computationally costly process.

This work introduces a novel method intended to conduct on-board attitude verification for small satellites using images showing Moon and Earth Horizon (MEH) in the same frame. As a first step of the method the MEH constellation is detected in the captured image by object detection. The angles resulting from the displacement of MEH from the center of the camera frame are determined using geometric relations. Using only Earth's horizon, two out of three rotational degrees of freedom can be determined. If the Moon is captured, the remaining degree of freedom can be solved. Using knowledge of the position of the Moon, the relative displacement in the image can be transformed into the satellite's attitude in a body-fixed frame. Finally, the attitude is transferred into Earth's inertial frame and output as a quaternion.

This method is tested on-ground with imagery taken by TU Berlin satellites. These satellites feature cameras that not only vary in resolution but also in the recorded spectrum: Images in the VIS and IR spectrum are analysed, and the results compared. To calibrate the settings for object detection, the quaternions determined with this method are compared with those measured by the on-board sensors of the respective satellite. Settings for object recognition are iterated to identify the best suiting settings for each satellite. Additionally, the implementation of MEH recognition software on a FlatSat is conducted successfully. Especially high-resolution imagery delivers attitude determination accuracy which favours the approach of attitude verification with this method. IR imagery is expected to provide higher accuracy compared to VIS imagery. In IR, the high intensity gradients between MEH pixels and the surrounding space make the detection of objects more accurate, as bright MEH pixels are clearly distinguishable from the dark background. The software is adaptable to different types of small satellites and camera payloads. This work provides further steps towards optical attitude verification on-board small satellites.