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VISUAL SERVOING FOR COORDINATED PRECISE ATTITUDE CONTROL IN THE TOM SMALL SATELLITE FORMATION

Abstract

Formations of multiple satellites observe target areas on the Earth's surface from different perspectives, enabling construction of 3D surface maps by photogrammetric methods. Main objective of TOM (*T*elematics Earth *O*bservation *M*ission) is to monitor ash clouds during volcanic eruptions with a satellite formation consisting of three CubeSats. TOM is Bavaria's contribution to the multi-national *T*elematics *I*nternational *M*ission (TIM), composed of 7 satellites by partners from 4 continents.

To achieve sufficient overlap of the images for the usage of photogrammetric methods, very precise and coordinated attitude control of the satellites is necessary. Especially for CubeSats with limited power and size, this poses a challenging task. This paper presents a vision-based attitude and orbit determination approach using image data to calculate the control input, also referred to as visual servoing. Thus, the cameras and data processing capacity onboard the CubeSats will be used for both image acquisition and attitude determination, eliminating the need for additional precise attitude sensors like star trackers.

To perform visual servoing, highly distinctive features are identified and tracked in the images. The control input for reaction wheels is calculated from the movement of the features between consecutive images. To ensure that the images captured by the different satellites overlap sufficiently for photogrammetric processing, the satellites track the same target area based on feature data exchange directly between the satellites. Thus, the camera system acts in dual-use as payload for 3D-surface imaging and as part of the AOCS (attitude and orbit control system).

Simulations of realistic scenarios based on the TOM project show the applicability of the presented attitude control approach. In a first step, a software-based Earth observation simulator generates the acquired images, demonstrating feasibility to compute and track features in satellite images to compute the AOCS input. In the second step, hardware-in-the-loop (HiL) simulations allow to realistically characterize the performance of this approach. This HiL environment utilizes two high-precision/high-dynamics turntables as 3-axis attitude simulators, where the satellites with their cameras are mounted, while the observation target is mounted on a mobile robot to simulate the relative orbit motion. This unique combination of different robot types (turntables, mobile robots) allows to realistically simulate relative dynamics during the observation process. The HiL simulation results will be further detailed in the final

paper to characterize the quality of the visual servoing approach, related to achievable accuracies and to robustness with respect to disturbances, as well as to required computational resources.