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ABSOLUTE VISUAL SERVOING FOR PRECISE EARTH TARGET POINTING ONBOARD SMALL SATELLITES

Abstract

Earth observation and high-bandwidth communication applications impose high demands on the attitude and orbit control system (AOCS) of a satellite in order to achieve precise pointing to the observation target or the ground station on Earth. Zentrum für Telematik e.V. (ZfT) is currently working on missions in both application areas: TOM (Telematics Earth Observation Mission) and CloudCT are two satellite formation missions for Earth observation; QUBE, QUBE-2 and LoLaSat (Low Latency Satellite) are satellite missions demonstrating different communication technologies.

To achieve precise pointing to a specific location on Earth, it is necessary not only to control the satellite's attitude, but also to know its exact position in orbit. Therefore, these satellites mostly rely on star trackers for attitude determination and GNSS receivers for orbit position determination. An alternative to achieve the required precise pointing is vision-based attitude control utilizing onboard cameras, also referred to as visual servoing. In previous work conducted at ZfT, a visual servoing approach for coordinated attitude control of multiple satellites in a formation has already been developed and extensively tested. The goal of this approach is the joint tracking of the same target area to enable sufficient image overlap for photogrammetric postprocessing. Since the attitude of all satellites is controlled based on the pointing of a designated leader satellite, this method is called relative visual servoing.

This paper will present a modified visual servoing approach which enables the precise pointing of a single satellite towards a specific location on Earth's surface. Ground control points (GCPs), i.e. points or structures on the surface of the Earth of known location and with unique appearance in satellite imagery, are used to determine the absolute attitude and position of the satellite. This approach is referred to as absolute visual servoing. The knowledge of the satellite's attitude and position is used to calculate the control inputs for its reaction wheels to achieve the required precise pointing towards the desired target.

In the paper, the operating principle of the absolute visual servoing approach is described. Different onbard image processing algorithms to identify and track ground control points are investigated and evaluated. The equations to determine attitude and position based on the tracked ground control points as well as the control law are presented. Simulations of realistic application scenarios using an Earth observation simulator and a hardware-in-the-loop (HiL) setup are performed to show the feasibility of the presented attitude control approach.