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AIM Autonomous GNC for close proximity operations

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Abstract

The AIDA program is a collaboration between ESA and NASA with the main purpose of investigating the effect of the kinetic impactor technique for asteroid deflection. The DART spacecraft (from NASA) will collide with the moon of a binary system (Didymos) while the AIM spacecraft (from ESA) will study the effect of such impact. AIM will rendezvous with Didymos before DART impact to perform its characterization and to test autonomous navigation techniques that will allow the spacecraft to safely get closer to the system.

For a deep characterization of Didymos, several instruments are included as payload and to get the necessary resolution a detailed characterization phase has been included in the mission timeline. During this phase, autonomous attitude pointing will improve science return and instruments measurements as it will allow to get closer to the target without losing it from the field of view of the navigation camera. To be able to operate the spacecraft in this condition, centroiding techniques and relative navigation algorithms have been investigated and implemented in the AIM GNC prototype developed by GMV, then tested through high fidelity simulations that include image generator tools in the loop (e.g. PANGU). Specific autonomous and semi-autonomous attitude guidance algorithms have also been developed taking into account experience from previous ESA missions.

An even closer approach, up to few hundred meters, has been studied for the purpose of delivering a lander/cubesat or in case the Radio Science Experiments will be done to measure the gravity of these small objects (780 m diameter the primary and 160 m diameter the secondary asteroid). Results show that at this close distance from the binary system the precision of centroiding algorithms is not enough to achieve required performance and to guarantee safety, especially when the body covers the entire field of view of the camera. For this scenario, relative navigation algorithms through feature tracking have been used and tested in the AIM GNC prototype up to Hardware-in-the-loop (HIL) for both nominal GNC chain and FDIR at GNC level. HIL tests have been run with the AIM Framing Camera (AFC), qualification model of the Dawn framing camera which has been adopted from the Dawn mission (NASA). GMV facility in Spain counted on the availability of both the optical and the robotic laboratory (***platform-art©***) to recreate the space-like conditions needed to operate the AFC space qualified camera.

The in-house heritage acquired in the frame of the Marco Polo / Marco Polo – R missions has been re-used and has been consolidated in the frame of the AIM project adapting the delivery strategy to a fly-by approach that guarantees collision free trajectories.

In this paper, the design of the GNC and image processing algorithms described above will be reported, together with the validation process and the results obtained during the test campaign at MIL level in Matlab/Simulink and at HIL level with the Dawn camera in the loop in the GMV facilities.

This paper is considered to be in the Mission & Campaign Design area, as also mentioned in the last point of the area description.