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GROUND TESTING OF VISION-BASED GNC SYSTEMS BY MEANS OF A NEW EXPERIMENTAL FACILITY

Abstract

Increase in spacecraft autonomy is a consolidated trend in new space systems. A field in which a high degree of autonomy would give the major benefits is Guidance, Navigation and Control: the possibility to perform Hazard Detection and Avoidance, or close maneuvers around different targets would open entirely new possibilities in space exploration, on orbit servicing, formation flying. Vision-based navigation is a promising technology to answer the challenge, but the necessary robustness can be ensured only with in-depth testing and validation: analog facilities can simulate different maneuvers in a scaled environment, supplying repeatable and controllable datasets. A new experimental facility recently developed at Politecnico di Milano, Aerospace Science and Technology Department (DAER) is here presented. The system core is a 7DoF robotic arm that moves a navigation camera reproducing the spacecraft dynamics around a target. Different targets are provided: a lunar terrain diorama for planetary landing simulation; a satellite mock-up for proximity GNC for rendezvous, docking and on-orbit servicing; an asteroid model to simulate proximity flight around small celestial bodies. Realistic, controllable illumination is provided by means of an adjustable small beam spotlight, and a dimming system excludes undesired light, reflections, and diffuse illumination. The system is designed for flexibility: it can follow predefined trajectories, operating as a simple dataset generator; software-in-the-loop simulations are possible by coupling GNC with the spacecraft dynamics simulation. Different scale factors can be selected, simulating different phases of landing or close approach maneuvers. The system is upgradeable to perform real time hardware-in-the-loop simulations, with also the possibility to include additional sensors (eg. IMU, laser altimeter). The ground truth trajectory should be known with an accuracy at least one order of magnitude better than algorithms under test: in practice, the actual required value depends on the scale factor adopted in the simulation. The target shape is reconstructed through dense matching techniques: several images are taken from positions all around the target: relevant features are extracted and matched across different frames to identify the camera pose in each view. This information is exploited to build a dense point cloud model with a sub-millimeter accuracy; laser measures are taken at selected points to validate the results, obtaining a reliable low cost alternative to more expensive systems. Two different algorithms, developed at DAER, have been tested: a feature-tracking relative navigation system, and a hazard detection system based on artificial neural networks. Preliminary results are shown and discussed.