IAF SPACE SYSTEMS SYMPOSIUM (D1)
Interactive Presentations - IAF SPACE SYSTEMS SYMPOSIUM (IPB)

Author: Dr. Stefano Silvestrini
Politecnico di Milano, Italy

Dr. Andrea Colagrossi
Politecnico di Milano, Italy
Prof. Michèle Lavagna
Politecnico di Milano, Italy
Mr. Robin Biesbroek
ESA european space agency, The Netherlands

PROCESSOR AND HARDWARE IN THE LOOP GNC TESTING FOR E.INSPECTOR MISSION: MULTI-SPECTRAL IMAGE PROCESSING FOR UNCOOPERATIVE TARGET INSPECTION

Abstract

Spacecraft debris poses significant threats to operational satellites and future space missions. The e.Inspector mission, currently under phase B, is an ESA funded mission aimed at flyaround a debris – 600 km height flying - to precisely reconstruct the target shape and dynamics in preparation of its capture for removal. This study presents a comprehensive approach for debris target detection employing optical and infrared cameras, integrated with a full image processing algorithm executed on the engineering model of the embedded camera processing unit.

The research methodology involves two distinct testing phases: Processor-in-the-Loop (PIL) and Hardware-in-the-Loop (HIL). In the PIL phase, the image processing algorithm is run on a processor to evaluate its functionality, computational time, intrinsic delays and efficiency. The algorithm is implemented on the Xiphos Q8 built around the Xilinx Ultrascale+ FPGA for HIL testing. HIL testing includes the integration of the two cameras (VIS and TIR) with the embedded system, a robotic arm and target debris mockup, enabling realistic simulation scenarios. Calibrated images are acquired using optical and infrared cameras to replicate space debris encounters accurately.

Results from both testing phases demonstrate the algorithm's efficacy in detecting and debris objects in various environmental conditions. The embedded implementation showcases high-speed processing capabilities suitable for real-time debris monitoring applications.

The GNC-IP architecture features two main submodes depending on the distance from the selected target. In particular, the main difference is the image acquisition strategy and consequent processing.

When the target is only few pixels in the cameras FOV, namely at the initialization of the proximity phase, long exposure images are foreseen. Whereas, as soon as the target blob increases to few tenths of pixel the frame acquisition is static. In the close-range submode, the target spans at least few tenths of pixels in the camera frame for both TIR and VIS cameras. The acquisition rate of the camera is taken as 0.1 Hz, conservatively to acquire and process both images. Such frequency is subject to extensive test with hardware in the loop. The image processing module computes two independent detections for the VIS and TIR image and fuse the information at the detection feature level, both for long and short exposure.