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VISUAL SERVOING FOR DEORBITATION AND SERVICING OF A NON-COOPERATIVE TARGET IN SPACE: A TOP-DOWN APPROACH WITH A SINGLE IMAGING SENSOR COUPLED WITH A FPGA/DSP HARDWARE PLATFORM

Abstract

In this paper we provide a thorough analysis of a class of algorithms designed to serve as an unsupervised, real-time servomechanism for space debris handling. From the very beginning we assume that the handled target is known, but completely non-cooperative, and therefore we rely on 2D visual information only. Another crucial constraint is limitation to a single camera only, and this is an immediate consequence of limitations imposed on payload mass and available energy budget. Hence, the hardware to realize our algorithms is limited to single imaging sensor, a single FPGA, a single DSP, and memory modules. Therefore, each algorithm in the proposed class fits into a general top-down framework which has already been presented during IAC-16 [paper 33960]. This framework structure allows us to decompose the solution into smaller, maximally decoupled functional blocks with well-defined interfaces, functional requirements, interoperability requirements, and computational complexity limitations. Therefore, each algorithm is made up of the following exchangeable blocks: texture and geometry extraction, matching against the model, pose and linear shift calculation, velocities calculation, forward time evolution for compensation of algorithm processing time. In this way, no matter how each and every component is wired internally, the whole visual servomechanism algorithm provides the target's pose and velocities for the moment the data is actually output. In this paper we present how the framework approach described above works in practice. For extraction of the texture from the current view we test SIFT-like features and SURF-like features. For extraction of geometry from the current view we test variants of the Harris corner detector and the Canny edge detector. For feature matching we test the ORSA algorithm and some other variants of RANSAC algorithms. For pose and linear shift calculation we use standard fundamental matrix methods; additionally we test the *a contrario* model which combines the last two into a single step. Finally, we test several numerical schemes for calculating derivatives and solving Euler equations of motion. All the testing mentioned above is done against a test set of images depicting the tumbling motion of the Iridium satellite mock-up; this set was acquired with a camera, using a tailored motorized test bench able to simulate almost all trajectories of the mock-up. For every algorithm, being a combination of subalgorithms enumerated above, we present results in a form of Euler angle plots. This allows us to pinpoint weaknesses and analyze accuracy of individual components.