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GENERAL FRAMEWORK FOR NON-COOPERATIVE SATELLITE'S TUMBLING MOTION ESTIMATION USING A SINGLE IMAGING SENSOR AND AN FPGA/DSP HARDWARE PLATFORM

Abstract

In this paper we propose a general framework for visual measurement of pose and angular and linear velocities during rendezvous with a non-cooperative satellite using only target's texture data obtained from a sequence of 2D images acquired by a single camera. The proposed framework is tailored for development of algorithms providing low-latency feedback for robotic grasping systems used for detumbling and deorbitation of space debris. The proposed framework is modular and its construction is prepared to be useful in proceeding according to ECSS standards for FPGA/DSP systems design. Since the framework is intended for FPGA/DSP platforms working in low energy budget regime, we assume availability of a single imaging sensor only with no active depth scanning; anything more would be a plus. We thoroughly discuss applicability of various state-of-the-art image processing techniques and point out computational complexity of these. We come to a conclusion that in order to extract instantaneous pose, it is enough to process the texture information in a single acquired view and match it against an internal view database. However, lower computational complexity comes at a cost of increased needs for memory capacity which will finally put a load on internal system buses; we also discuss this issue and conclude that this increased traffic poses no problem in the FPGA/DSP hardware architecture. From the point of view of image processing, the algorithmic outline of the concept is as follows. During the cold start of the algorithm, that is when nothing is known, the currently visible texture is matched against the whole texture database containing various poses of the target satellite; this database must be prepared and uploaded beforehand. In the running state, that is when the previous state is known, the currently visible texture is matched against those database poses which are in the neighborhood of the match found previously and the size of this neighborhood depends on quality of the previous match. The matching process is based on the ORSA algorithm which allows fast rejection of obviously non-matching candidates. As a result we obtain information on how the two underlying texture feature clouds match together. This in turn allows us to compute the fundamental matrix which encodes their relative rotation and translation. Therefore, once the best-matching texture is found, current satellite's pose in some fixed coordinate system is also retrieved. In this way we build the trajectory of the target and compute angular and linear velocities.