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VISION BASED ATTITUDE DETERMINATION USING A SIMULTANEOUS LOCALIZATION AND MAPPING ALGORITHM DURING RELATIVE CIRCUMNAVIGATION OF NON-COOPERATIVE OBJECTS

Abstract

Vision based navigation has been already demonstrated in missions that involved rendezvous and docking operations between satellites. While maneuvers between cooperative targets have been tested in orbit, limited experience is available in the case of non-cooperative objects, such as debris or malfunctioning spacecraft.

The possibility of fixing and refurbishing out-of-order satellites with unmanned vessels might give rise to a multi millionaire business: nowadays, a lot of space agencies and private companies are pushing in this direction, and are triggering the interest in researching close approach maneuvers and On-Orbit Service operations (OOS).

In this paper, we approach the problem of a chaser satellite circumnavigating a non-cooperative target: the objective is to obtain a precise map of the scenario and to measure the relative attitude of the target, in order to subsequently perform proximity operations (active debris removal, rendezvous, servicing, etc.). This work focuses on two non-cooperative targets: first, we analyze the case of a malfunctioning spacecraft in need for servicing and, secondly, the case of a meteoroid-like debris to be removed.

In both cases, the chaser has a vision sensor and observes a set of landmarks on the target; the control acts on the yaw-rotation of the detector in order to maximize the time dedicated to landmark observation. By defining a probability distribution over a set of feasible control trajectories, we perform the search for a near-optimal solution. An Extended Kalman Filter computes the state uncertainty, which is used to design a cost function based on the trace of the covariance matrix for the state estimate. At the core of this approach resides the cross entropy technique for estimation of rare-event probabilities, which iteratively approximates the sampling distribution towards regions of progressively lower cost until converging to the optimum. Finally, by inserting an inner control loop that tracks the target state space changes, it is possible to obtain a unique quaternion representation of the target's real time attitude.

In this work we present simulations for both scenarios (spacecraft and debris), demonstrating the validity of the control technique. Performances of the policy are compared with a traditional PID control by evaluating the residual uncertainty bounds on the landmarks. Results confirm the validity of this approach, which allows for accurate localization and mapping of a target along with a precise quaternion representation of the attitude, whose steady state error asymptotically converges to zero.