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PERFORMANCE ANALYSIS OF THREE DIFFERENT COST POLICIES FOR THE CONTROL OF A CAMERA IN RELATIVE CIRCUMNAVIGATION SCENARIOS

Abstract

Autonomous relative navigation has been the focus of intensive research lately due to its potential impact on spacecraft proximity operations (OOS). Such operations, consisting of monitoring, servicing and docking, are of fundamental importance in future missions. The striving for autonomy is strictly dependent on the capability for a satellite to identify its position with respect to another target.

State of the art proximity-navigation policies solve the problem of control and estimation separately. That is, the mutual effects that the controller induces on the estimator (and vice versa) are not considered. In this work, we depart from the separation principle of stochastic control, thus integrating planning and stochastic optimization with localization in order to perform control of autonomous spacecraft under uncertainty conditions.

We approach the problem of a chaser circumnavigating a target in a three dimensional orbit. The chaser has a vision sensor and observes a set of landmarks on the target: its goal is to obtain a detailed map of these features. The control acts on the yaw-rotation of the sensor in order to maximize the time allocated to landmark observation. An Extended Kalman Filter (EKF) provides the state uncertainty, which can be used to design a cost function. Since the optimization problem is troublesome to solve, we resort to cross-entropy (CE) minimization, which iteratively searches for the near-optimal path. The final result is a trajectory that achieves the predefined goal in the state space and that reduces the total localization uncertainty, whilst limiting the actuation costs.

In this work, four different cost functions are designed and simulated, and their performances compared with the case of a fixed, nadir-pointing camera. The analysis of localization uncertainties for a different set of initial conditions confirmed the superior performances of our novel control policies.

The algorithm was then further challenged by adding some obstacles: a solar panel and parabolic disk mockups were introduced in the map, limiting the field of view of the detector. We illustrate in the paper how our technique outperforms the traditional navigation policy and permits the localization of landmarks that would have been ignored if the traditional approach had been used.

Finally, the approach was tested on a 5 DOF satellite simulator, using a spacecraft mockup and an irregular shaped object, whose surfaces were equipped with landmarks. Results from the campaign confirmed the simulated performances and are paving the way for future developments.