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SYNTHETIC VARIABLE-BASELINE VARIABLE-ORIENTATION STEREO CAMERA SYSTEM FOR RELATIVE NAVIGATION IN CLOSE PROXIMITY

Abstract

Given the high number of inactive satellite orbiting and polluting the space around the Earth, In-Orbit servicing missions will play a substantial role in the industry in the upcoming decades. These missions could potentially revive numerous satellites through refueling or minor repairs, thereby reactivating valuable assets in space.

Among the various techniques envisioned as possible solutions to the problem, the use of Space Manipulator Systems (SMS), i.e. servicing spacecrafts mounting manipulators on-board, is particularly interesting, as it offers great flexibility. Designing this kind of missions, however, is often challenging.

As the system moves in close proximity of the target spacecraft, correctly estimating its position and attitude is paramount in order to avoid undesirable collisions. On this matter, studies have shown that relying on the direct kinematics of the manipulator to reconstruct the pose of the end-effector as a function of the spacecraft base pose and joint variables of the arm lacks robustness and does not meet the error thresholds required to enable this kind of technology. This problem can be mitigated using the direct measurements of a sensor mounted in the vicinity of the end-effector of the manipulator. While lidar sensors and stereo cameras necessitate higher power and mass budgets, opting for monocular cameras can mitigate this issue, albeit at the cost of reduced accuracy.

This paper proposes a novel approach in which an UnScented QUaternion Estimator (USQUE) is used to concurrently perform non-linear filtering on the attitude and position of both the base of the chasing spacecraft and the end-effector of the manipulator within a fully relative framework. This is achieved exclusively through information derived from two cameras mounted, respectively, on the spacecraft base and the manipulator end-effector, effectively creating a variable-baseline stereo camera system.

The results demonstrate the efficacy of the method, showcasing high accuracy in the reconstruction of the position and orientation of both the reference frames of interest.

As a secondary outcome, a high-fidelity model of the Space Manipulator System (SMS) is generated using Modelica. This model also incorporates a fully relative representation of gravitational acceleration in the Local-Vertical Local-Horizontal (LVLH) frame centered on the target. This approach circumvents potential numerical challenges stemming from the significantly smaller distance between the target and servicing spacecraft compared to the one from the center of gravitational attraction. Additionally, it preserves the possibility to incorporate gravitational perturbations into the modeling, a consideration often overlooked in the related literature.