Challenges of pose estimation for future OOS missions

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Abstract. One of research areas at On-Orbit Servicing Group, German Aerospace Center (DLR), is developing and testing robust visual pose estimation techniques for visual navigation. Currently we are working with cameras, which have different field of views, and a lidar. It is important to keep in mind, that developed image and point cloud processing techniques must be robust and reliable during whole operational range. Our research activity is in the close range from 20 up to 3 meters. This talk gives an overview of different challenges of image processing (IP) and pose estimation (PE) of non-cooperative target, which were faced during investigation, testing and post analysis phases.

Keywords: image processing · pose estimation · On-Orbit Servicing.

1 Introduction

With an increase of launching more new satellites into space in the last decade, there is also a need for a more careful monitoring and maintenance of space environment. Space debris present a very critical problem since more often the evasive maneuvers are needed by operational satellites and other spacecrafts in order to avoid the collision. At German Aerospace Center we do research in the field of On-Orbit Servicing (OOS) and Active Debris Removal (ADR). In these terms, different activities can be planned for these missions, e.g. repairing, modernization or lifetime extension of a satellite. In case of no more functioning satellite or remains of rocket body, complete deorbiting of that objects is considered. Any of these activities need a safe approach of the servicer spacecraft towards the space object. In the close ranges the autonomous systems rely on visual navigation with cameras and/or lidars for estimation of position and orientation of a non-cooperative target. Developing of reliable flight-ready pose estimation techniques for such systems is a challenging task.

2 Challanges and Discussion

During developing and testing visual pose estimation techniques for the estimation of the target pose (position and orientation) different problems must be solved. From the experience gained during research and development phase they are following:

1. **Simulation scenarios and illumination conditions.** At DLR, there is a testbed for proximity operations in a close range, called EPOS 2.0 [2]. With this Hardware-in-the-loop Simulator (HiL) we are able to simulate complex approach scenarios of the chaser spacecraft to a non-cooperative target space object. Even so, there is a precise facility to test the rendezvous scenarios, can we really recreate every possible approach scenario with suitable illumination environment on the ground?
2. **Geometry model of the target.** Before the mission takes place, we approximately know the 3D geometry model of the non cooperative object to which we are going to approach. The 3D mesh model can be be defined as very precise model and therefore be very heavy for IP or only keypoints can make up the 3D mesh. The robust feature extration pose estimation we are currently developing based on the knowledge of the 3D mesh. From the technical point of view, we decided to have only keypoints for the IP. But to define the keypoints for the mesh is very challenging task. There is no defined consensus to select the keypoints. One can just extract the keypoints by visual perseption or use some techqniues for automatically extraction of the keypoints [3][4].
3. **Data quality from visual sensors.** In the visual naviagtion, the data quality from the sensors plays crucial role for any pose estimation. For the cameras and lidars, it is necessary choose and evaluate sensors technical charasteristics on the ground. It is also important to test the sensors under different illumination conditions to define their pros and cons. The navigation system must also be prepared to have a solution for the case when there is no visual data.
4. **Input parameters for image processing technique.** The IP and PE techniques depend on some input values. What is an appropriate set of input values? These can be choisen by different tests on the ground [1]. The one question which is difficult to answer is - are these input values valid for the whole range of application and for every possible approach scenario?
5. **Suitable for on-board computer (OBC)?** Fast implementation of an algorithm with an open source libraries at PC to check if it suits for IP and PE is not the same as implementation on OBC. The main question which should be answered is - if the IP performance time fast enough with the OBC for a planned mission? For the best case, no third libraries must be used during the development phase to ensure a better migration.

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