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Visual Servo Based Space Robotic Docking for Active Space Debris Removal

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ABSTRACT

Space robotics is an important area of research as it can help lower costs of satellite launches and increase the lifetime of current missions. Being able to remove space debris is beneficial for future space usage. Currently, over 500,000 pieces of debris with the ability to damage satellites are tracked from Earth. This number is larger for debris that is too small to track, such as paint chips and bolts. The Kessler Syndrome states Low Earth Orbits can become inaccessible as debris accumulates. Autonomous space robotic systems are needed to get ahead of this problem. Space robots can also be used for autonomously maintaining, repairing, and inspecting satellites. On-orbit servicing missions have shown economic feasibility in the past and this industry is currently growing. Autonomy allows for real-time detection of debris as they tumble and as they pass through different lighting conditions. Autonomy also overcomes communication latency and time constraints tele-operated space robotics systems have dealt with in the past. Unfortunately, the area of autonomous space robots has not advanced with the rest of the space industry due to high development costs and difficulties in simulating the space environment in lab settings.

Currently being set up at the Space Engineering Design Lab at York University is a robotics rendezvous and docking facility with two industrial robots to test effective methods for grasping objects in free fall. Being developed is an autonomous space robot system for debris collection and on-orbit servicing with two subsystems; a computer vision program capable of identifying the 6-DOF pose of a target, and an efficient control system. Development of an effective computer vision algorithm using machine learning is needed to overcome environmental changes due to lighting and changes in attitude of a target in real time. This can also aid in identifying debris of varying shapes and sizes. Neural networks are the backbone of computer vision applications on terrestrial robots, i.e., self-driving cars, and can be viable in space debris removal if optimized for space grade computers. Network architectures such as YOLO and Faster R-CNN already provide fast object identification and can be paired with regression-based orientation detection networks to efficiently learn a targets 6-DOF pose. Combined with effective control techniques, the system under development can detect and track a target, and then proceed to rendezvousing with the target.