A Vision-based LiDAR Sensor Technology for Space Debris Removal

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The vision-based navigation (VBN) sensor is the most technically demanding payload of a 100-kg class satellite to be launched in May 2017 by the Nanoracks Kaber deployment system installed on the International Space Station. The VBN sensor has been developed in view of space rendezvous and active debris removal applications. The implemented sensor architecture can also be considered for future automotive, unmanned vehicle (e.g. drone), cattle, and forestry management applications.

The activities of human beings in space have progressively generated a huge amount of garbage, to such an extent that today it is a concern for spacefaring nations. Satellites and orbiting debris collisions happened on several occasions. The International Space Station (ISS) modifies its orbit almost daily to avoid threatening debris.

Figure 1: Launcher tank recovered in South Africa. (Argus/Enver Essop).

In 2014, around 600 pieces of debris totaling 100,000 kg re-entered the Earth's atmosphere. In a little more than half a century, more than 4800 launches have placed some 6000 satellites into orbit. Less than 1000 are still operational today. The US Space Surveillance Network tracks and maintains a catalogue of more than 12,000 orbiting items. Objects larger than approximately 5 to 10 cm in low Earth orbit and 30 cm to 1 m at geostationary altitudes are monitored. Only 6% of the catalogued objects are active!

The most effective means of stabilizing the amount of orbiting debris is by mass reduction within regions with high densities of space debris. A credible solution has emerged over the recent years, which is to actively remove inactive objects.

The EC FP7 RemoveDEBRIS project/mission aims at performing in-orbit Active Debris Removal (ADR). The scenario of this low-cost mission (€11.3M) involves a microsatellite of 100 Kg, called RemoveSAT. It will eject and then capture and deorbit two space debris targets, called DebriSATs. Various rendezvous, capture, and deorbiting key technologies such as net and harpoon and LiDAR-based vision sensors will be evaluated in-orbit. Vision-based sensors are paramount for the success of ADR missions. They allow identification of the debris' geometrical features and main tumbling axis. No proximity navigation and capture can be envisaged without this information.

RemoveDEBRIS is one of the world's first and perhaps the most important in-orbit ADR demonstration. It is a vital prerequisite to achieving the ultimate goal of a cleaner Earth orbital environment. CSEM is part of a consortium led by the space department of Surrey University, with SSTL and Airbus as the main space industries. CSEM is responsible for the vision-based navigation (VBN) sensor.

The VBN sensor is made of two main sub-systems: a flash imaging LiDAR and a color camera. The innovation stands in the LiDAR as the camera is an off-the-shelf product. As it is a low-cost mission, most of the components are not space-qualified components. The whole system has been designed and realized by CSEM.

Figure 2: VBN sensor with laser head, LiDAR receiver, and camera.

The sensor's mass is 2 kg and its size is 10×10×15 cm^3. It is specified to take 3D images at a distance between 1 and 20−40 m.

Currently, the VBN sensor proto-flight model is functionally tested. Figure 3 shows the target used for these tests and Figure 4 shows a raw image generated by the LiDAR.

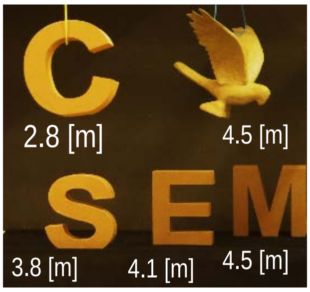

Figure 3: Target for the functional tests.

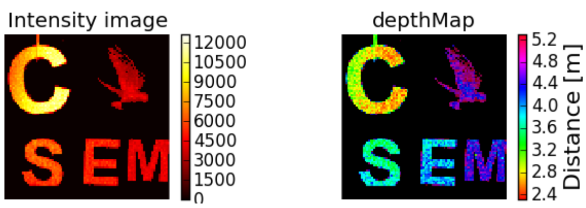

Figure 4: Images generated by the LiDAR (intensity on the left and distance on the right).

The LiDAR generates two images: one intensity image, like any camera, and a distance or depth-map image that provides the 3D information. Environmental tests and delivery to SSTL for integration on the satellite are planned for October and November 2016, respectively. The launch is planned for May 2017.

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