Miniaturized Flash Imaging Lidar for Space Robotic

A. Pollini, C. Pache

Imaging LiDARs (light detection and ranging), or in other words three-dimensional (3D) vision-based sensors, are considered as key enabling technology for various space applications. Applications include the control of automatic descent, and soft and precise landing on celestial bodies such as Mars or asteroids, or the control of on-orbit rendez-vous or automated removal of space debris. CSEM extended its capacities from scanning LiDARs to flash imaging LiDARs in the past years.

Imaging LiDAR supports the relative navigation spacecraft-target by providing to spacecraft GN&C (Guidance, Navigation and Control) system information. It is containing at the same time distance to the target, 3D map and radiometric measurements of the target derived from time-of-flight (ToF) images and intensity images. Most of the existing imaging LiDARs use mirrors to scan a laser beam over a defined target area. The 3D image of the target is reconstructed from measurements made at different scanning directions. Ther major drawback of imaging LiDARs are their high mass (>12 kg) and power consumption (>75 W). And they require complex and bulky scanning mechanisms, and provide relatively low image spatial resolution and repetition rate (~400x400 points per frame in ~6 seconds). Hence, sophisticated motion compensation technics shall be used at the same time as the spacecraft-target relative dynamics can be relatively high (up to 30 m/s). These systems are not able to achieve the desirable resolution (up to 1000x1000 points in one frame), the fast frame rate acquisition (frame rate >1 frame per seconds) and the relatively large observation field-of-view (>20 degrees) to meet the space mission requirements. The time available for the full image acquisition is a very critical parameter and is mainly limited by the measurement acquisition speed of the system (performing the scanning operation), the required high resolution of the image, the high velocities of the descent vehicle and, the time available and processing resources. Flash-type imaging LiDAR system is one possibility to overcome these drawbacks. In pure flash imaging LiDAR the target area is fully illuminated in one snapshot. ToF is measured on the LiDAR focal plane using a detector array with a high number of detector elements placed side-by-side in a 2D arrangements. Implementation of flash-type imaging LiDAR results in lower mass (4kg), lower power consumption (35 W) and lower system complexity and risk solutions. In addition, other effects such as image blur due to the motion can be minimized. In recent years CSEM became a recognized European innovator in the design of flash imaging LiDAR for space applications.

Today, CSEM is involved in several activities targeting the development of a flash imaging LiDAR to a Technology Readiness Level (TRL) of four. TRL4 means component and/or breadboard functional verification in laboratory environment.

In the mid-term, the objective is to maintain the leading role of CSEM in the design of flash imaging LiDAR for space applications and to cross the challenging gap between TRL4 demonstrators and engineering, qualification and flight models. In accordance with the Swiss space policy, these steps can only be achieved with the leading involvement of at least one Swiss industrial partner. In parallel, CSEM is investigating terrestrial applications fields such as metrology, driverless automotive vehicles and civilian applications of drones in order to identify additional potential markets for the technology.

CSEM was the coordinator of the project FOSTERNAV [1] which resulted in the demonstration of the first European multiple operation modes flash imaging LiDAR. The sensor architecture developed has now been scaled down to design a vision-based sensor that should be part in 2016-2017 of an in-orbit demonstration for Active Space Debris Removal [2].

Figure 1: FOSTERNAV demonstrator undergoing tests.

CSEM led the ESA MILS phase 1a project which aimed at investigating key technology bricks such as ToF matrix detectors, MOEMS mirror, Single Photon Counting (SPC) and In-Pixel Demodulation LiDAR architectures. This first project allowed CSEM to continue with the on-going MILA and CECILE ESA projects. MILA targets the development of a TRL4 traditional SPC flash imaging LiDAR, whereas CECILE aims at developing a TRL4 flash imaging LiDAR for space based on advanced image processing Compressive Sensing[3] technique.

These activities have received the support of the EC, ESA as well as funding from the Swiss Government: we are grateful for the support received.

---

[1] www.fosternav.net

[2] RemoveDebris: an EU low cost demonstration mission to test ADR technologies. V.Lappas and all. IAC 2014.

[3] Compressive Sensing LIDAR for 3D Imaging. Howland and all. CLEO2011