15th SYMPOSIUM ON SMALL SATELLITE MISSIONS (B4)
Small Satellite Operations (3)

Author: Mr. Frederik Belien
Delft University of Technology (TU Delft), Germany

Mr. Steven Engelen
Delft University of Technology (TU Delft), The Netherlands
Dr. Arash Noroozi
Delft University of Technology (TU Delft), The Netherlands
Dr. Chris Verhoeven
Delft University of Technology (TU Delft), The Netherlands

AUTONOMOUS NAVIGATION FOR TRANS-LUNAR NANO-SATELLITE MISSIONS

Abstract

With the ongoing miniaturisation of technology, the potential of nano-satellites for scientific operations increases. One such application is OLFAR, which uses a swarm of nano-satellites to map the last unexplored region of the radio-frequency domain with frequencies between 300 kHz and 30 MHz. However, sending a large number of nano-satellites to the Moon is costly and it is difficult to actively track and control each individual satellite. To overcome this, nano-satellites could autonomously navigate for which a sensor fusion method is proposed for increasing the accuracy and coverage of the combined onboard sensors. The sensor suite is also expanded with two navigation methods during two distinct mission phases: disc measurements during the low-thrust transfer and feature scanning once in lunar orbit.

Sensor fusion combines the measurements of all sensors related to position and attitude on the satellite, in order to obtain higher accuracy. It employs a decentralised Kalman filter, which first filters the data of each sensor separately, after which it combines the filtered data, which is subsequently forwarded to an optimal control algorithm to minimise propellant consumption. Afterwards, the thrust and attitude control data are fed back into the filter.

The traditional sensor set is expanded with an optical camera which, during the transfer phase, observes the closest main body (i.e. Earth or the Moon). It measures the angular size of this body, allowing for estimation of the relative distance. By using only two pixels on the horizon of the main body and combining this in the aforementioned sensor fusion process, the position error at 20,000 km equates equates to 5.6 km and at 380,000 km 106 km. This would be sufficient for a satellite to autonomously determine its trajectory during the transfer from Earth orbit into lunar orbit.

In lunar orbit, the system performs feature scanning on the lunar surface. The maria, for example, are easily recognisable and can be compared to a lunar map stored in a database aboard satellite. The size and position of the observed features not only provide the altitude, but also the position above the lunar surface. By using a staggered approach the computational load of this technique is reduced, whilst achieving an accuracy of better than 2 m.

These techniques allow for autonomous position determination for both nano-satellite and conventional satellite missions to the Moon. This also reduces ground station operations due to the increased level of autonomy.