Relative Navigation and Landing Site Detection Using LiDAR Data for Powered Descent on Small Planetary Bodies

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KaNaRiA-NaKoRa[1]

This project proposes the evaluation of GNC algorithms on a multicopter that emulates the dynamics of an asteroid lander. This system consists of: the *Model and Simulation Module (MSM)*, which simulates the spacecraft dynamics and disturbances, implementing the Guidance and Control routines as well as the landing site selection; and the *Multicopter Flight Module (MFM)*, that emulates the spacecraft dynamics from the MSM, and carries the Navigation payload [1].

The latter is composed by a 128-channel scanning LiDAR, in order to emulate the space-qualified flash LiDAR [2], whose image resolution is 128 × 128 px. A secondary 64-channel scanning LiDAR is added to augment the density of the first data set. This point cloud concatenation is the main measurement for the relative navigation solution. A tactical-grade FOG IMU is used for the estimation of the multicopter's inertial orientation.

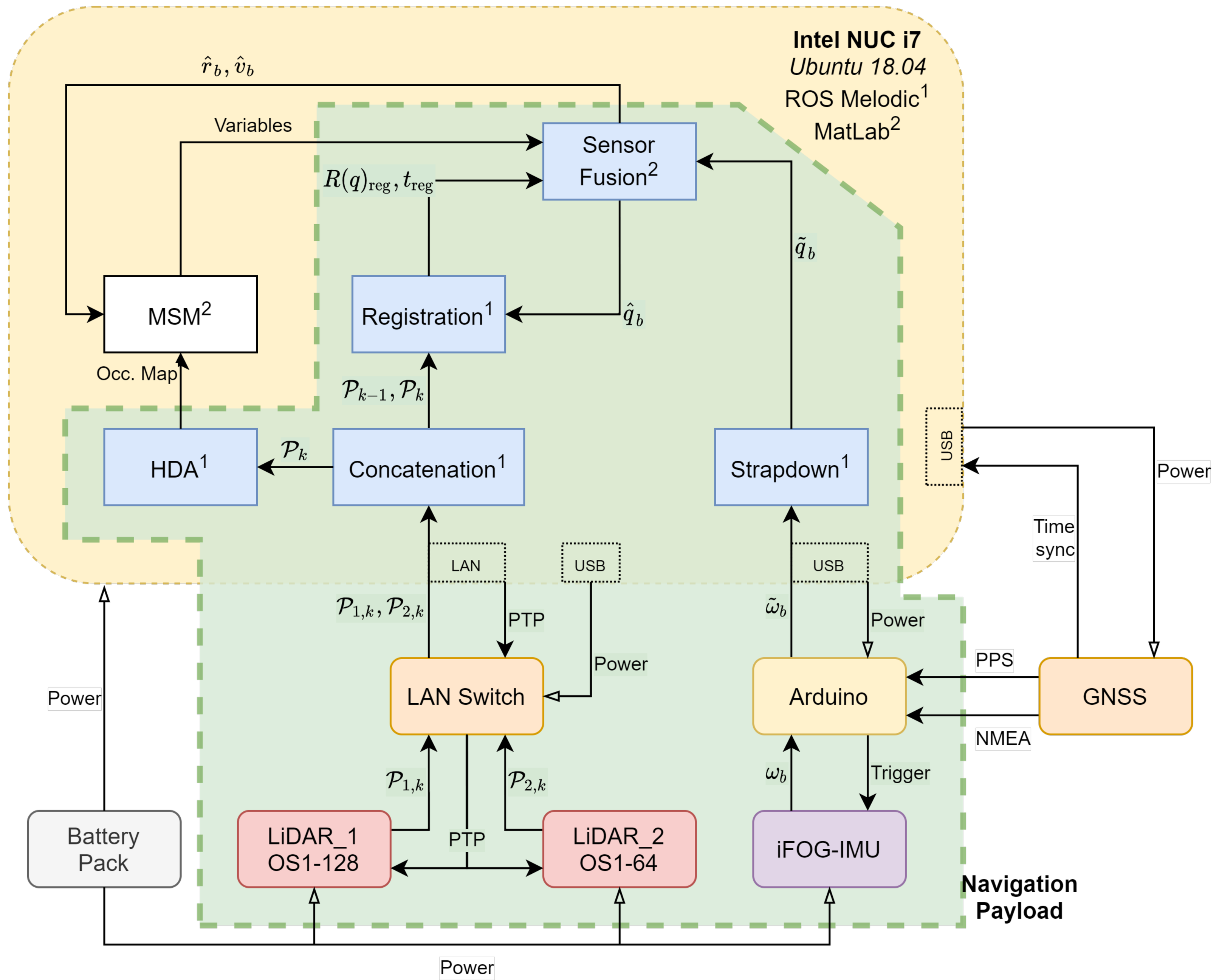

Figure 1. KaNaRiA-NaKoRa multicopter's navigation architecture

[1]**K**ognitionsbasierte, **a**utonome **N**avigation am Beispiel des **R**essourcenabbaus **i**m **A**ll - Entwicklung und Validierung autonomer **Na**hfeldnavigation **ko**operativer **Ra**umfahrzeuge zur Landung auf kleinen planetaren Körpern (In English: Cognitive Autonomous Navigation for Deep Space Resource Mining - Development and Validation of Autonomous Near-field Navigation of Cooperative Spacecraft for Landing on Small Planetary Bodies).

Surface's Features Estimation

It is based on the normal vectors estimation of the terrain surface due to the constraints for safe landing, as follow:

- the slope, lower than or equal to 15°
- the area, with a diameter greater than or equal to 5 m
- the roughness, defined as a maximum height variation of 0.3 m

The point cloud is segmented into landing and hazards [3] regions, input for producing a 2D projected occupancy map. The latter allows the recalculation of the original trajectory –if needed– as soon as new information from the navigation module updates the hazard map.

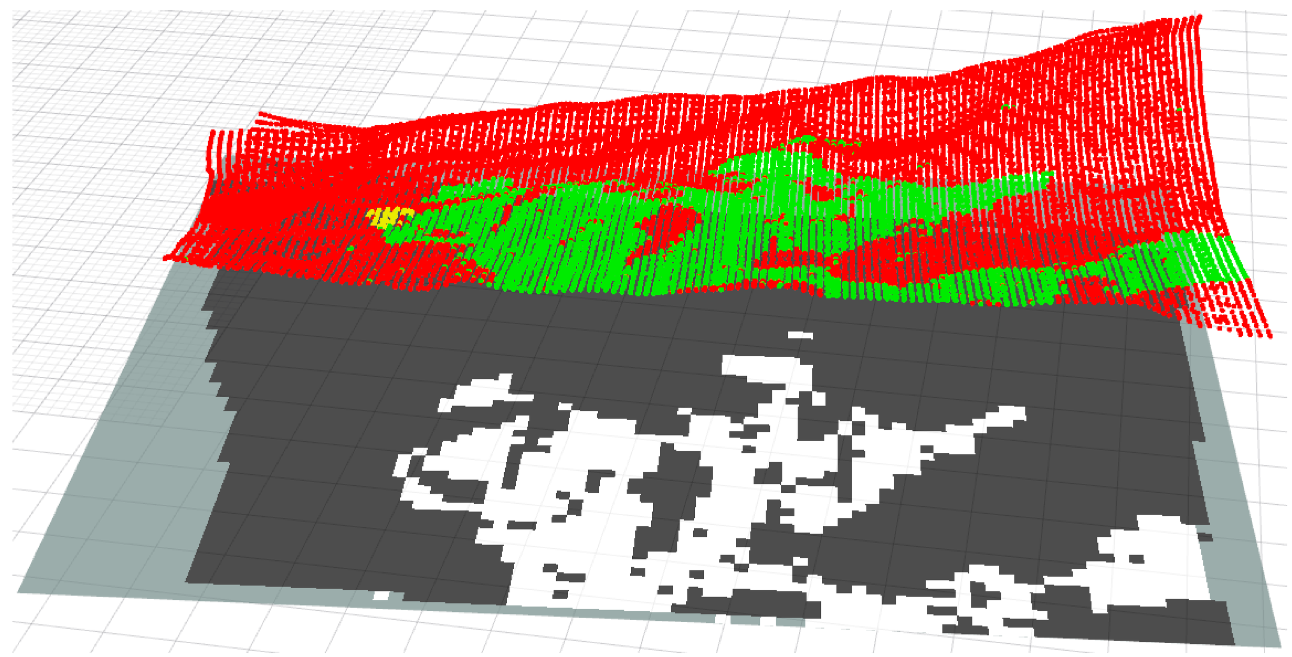

Figure 2. Landing and hazard point clouds, and 2D occupancy map

As the normal vectors estimation depends on the point cloud density, and the latter varies with the altitude of the lander, there is a negative exponential correlation. This is useful at changing the parameters for the normal vectors estimation, resulting in better defined hazard regions, thus an enhanced 2D occupancy map.

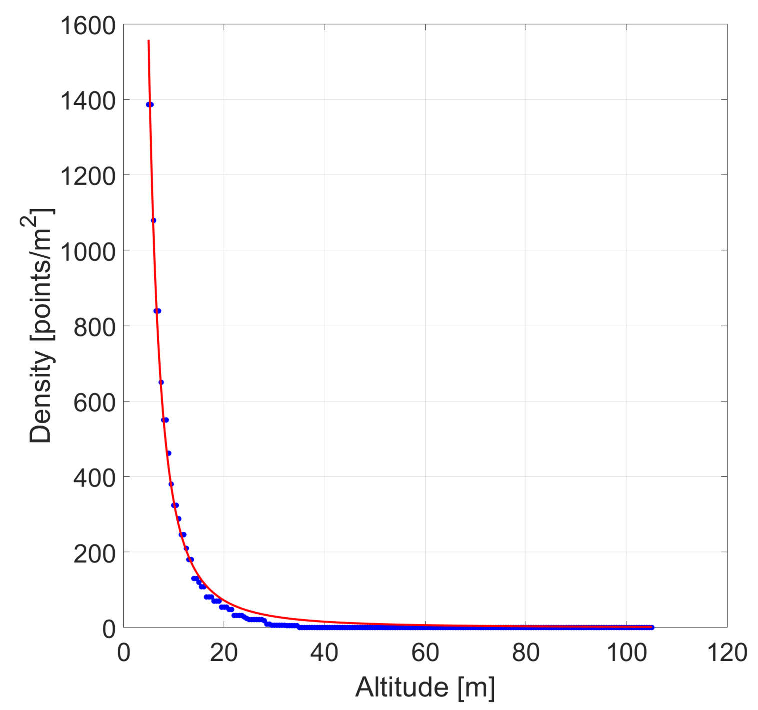

Figure 3. Variation of point cloud density with respect to the altitude

Relative Navigation Using Point Clouds

Rigid registration of two consecutive point clouds, using an initial attitude estimation from the FOG IMU, produces the correspondent rotation matrix and translation vector, and correspondent LiDAR odometry. These measurements are required for the estimation of the lander's state vector by means of an Extended Kalman Filter.

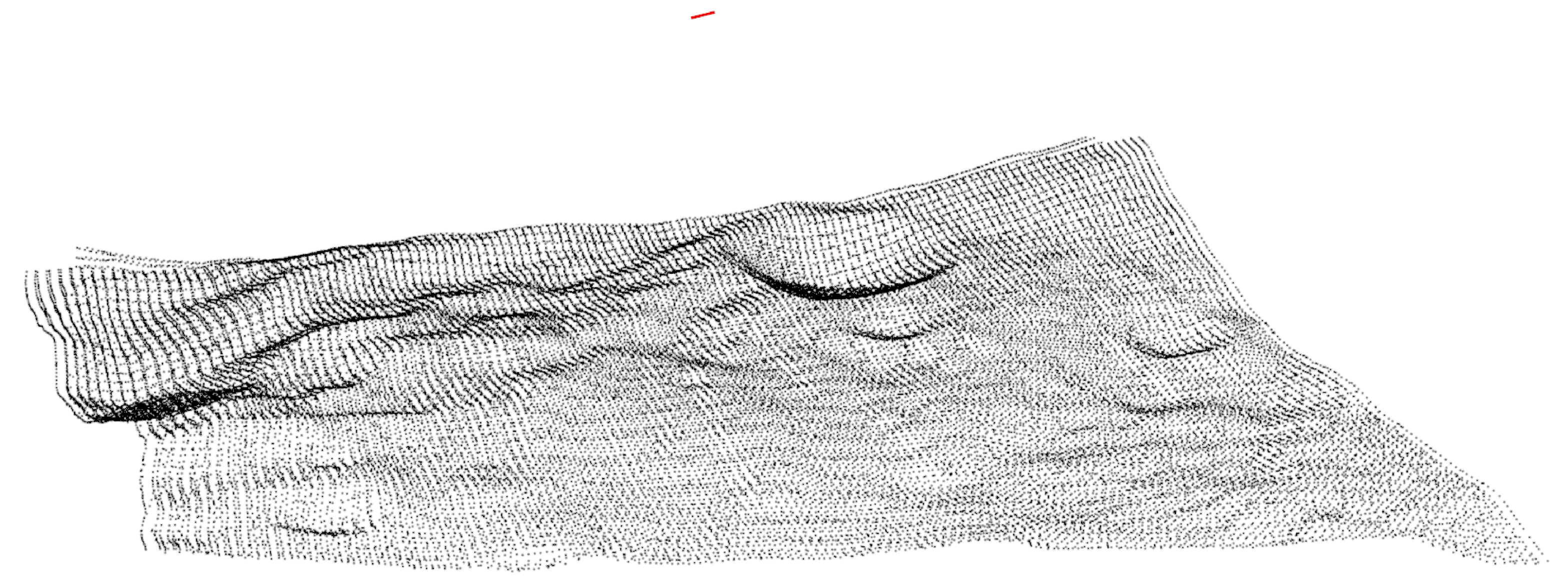

Figure 4. Resultant point cloud registration from two consecutive data sets, and displacement segment from right to left in red

References

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