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Digital Elevation Modeling from Aerobot Camera Images

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Abstract

We present an autonomous camera platform, the Aberystwyth University Aerobot, and an automatic reconstruction pipeline generating triangulated 3D surface meshes and DEMs from the acquired images. The performance of the pipeline is demonstrated on 30 images from an outdoor field test at Clarach Bay beach.

1. Scope

The FP7-SPACE EC Project PRoViScout [4] aims to demonstrate the feasibility of vision-based autonomous sample identification & selection in combination with vision-based navigation for a long range scouting/exploration mission on a terrestrial planet along with the robotic elements required [3]. One of the required steps during a scouting rover demonstration is the mapping of the region to be traversed by means of a camera mounted to an aerobot [6].

Aerobot-based mapping provides area context for the rover in the form of multispectral imagery that is used to generate both a terrain model for navigation and a mineralogical map to inform science assessment and mission planning.

2. Aerobot Image Capture

The Aberystwyth University Aerobot [6] is an autonomous camera platform suspended from a tethered helium balloon which is capable of operating up to a height ceiling of 100 m. It is equipped with a high-resolution wide-angle camera, position and orientation sensors, a wireless network link and a control computer, see Figure 1. The aerobot camera having a Sony ICX625 monochrome 2,448×2,050 pixels large CCD sensor can capture up to 15 frames per second at 8 or 12 bits per pixel. Currently, a lens with a focal length of 8 mm is used, giving a ground footprint of 53×44 m at a typical working altitude of 50 m with the projected ground pixel size 2.5 cm.

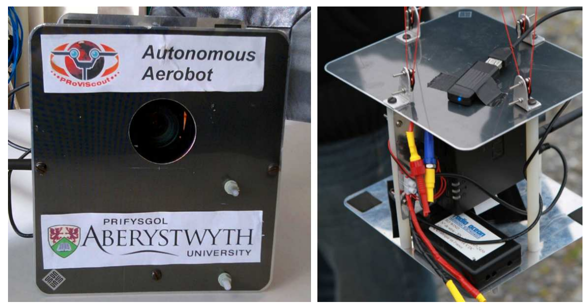

Figure 1: Aerobot prototype hardware.

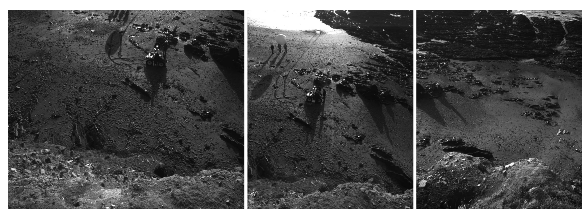

Figure 2: Example aerobot images from cliff-top.

An outdoor field test of the aerobot took place at Clarach Bay beach, Aberystwyth, during February 2011 as part of the PRoViScout project. Due to adverse weather conditions it was not possible to launch the helium balloon safely on that occasion. Instead, the aerobot was taken to a nearby cliff-top and pointed manually at the beach below, see Figure 2.

3. Image Data Processing

The aerobot camera is internally calibrated off-line (principal point, focal length, lens distortion) using standard calibration methods.

3.1. Generation of Triangulated Mesh

Bundler [5], a publicly available Structure from Motion tool, is used to calibrate the cameras externally (camera poses). Image feature detection and description is followed by exhaustive pairwise feature match-

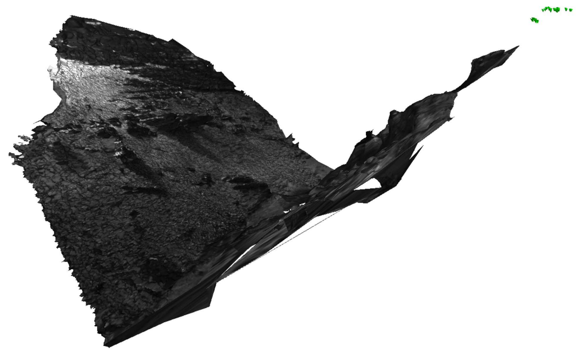

Figure 3: Virtual view of the textured triangulation of the 3D point cloud created from 30 aerobot images.

ing and geometrical verification. SURF image features with a strict detection threshold 75,000 are used in order to reduce the number of features detected on rough sand. Global calibrations are attained by growing the 3D model from the most promising image pair.

Knowing camera calibrations, dense 3D reconstruction can be computed using the approach proposed in [2]. It is based on the minimal s-t cut of a graph derived from the Delaunay tetrahedralization of the input 3D point cloud in order to label tetrahedra as inside or outside. The resulting surface is the surface separating the empty space from the full one. The method also uses a visual-hull to reconstruct the difficult surfaces which are not sampled densely enough by the input 3D point cloud, see Figure 3.

3.2. DEM Generation

A useful mapping structure for path planning and mineralogical assessment is a Digital Elevation Model (DEM) and a corresponding orthographic image. The camera poses revealed in the previous step are used together with dense correspondences, i.e. disparities, between adjacent images to reconstruct 3D points in space that fit into the rectangular DEM structure [1].

Figure 4 shows the result of this process. The scaling of the DEM is still arbitrary and will be refined making use of known objects in the scene. As the aerobot is tethered to the rover, the rover dimensions can be used for proper scaling of the mapping results.

4. Discussion and Outlook

On hardware side, it is planned to add a filter wheel to the aerobot camera to give it multispectral capability and enable spectral analysis and ultimately mineralogical classification of the terrain below the aerobot.

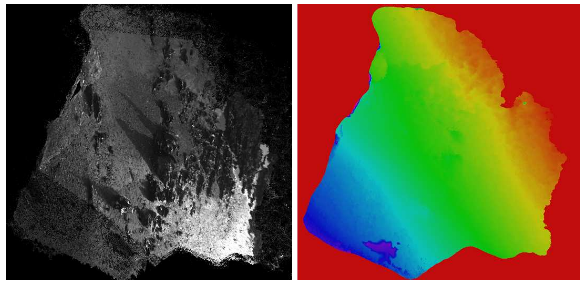

Figure 4: Overview with diameter about 40×40 m: Ortho image (left) and DEM (right; color coded elevation: orange = 0 m, blue = 5 m, red = undefined).

The mapping pipeline will be applied during a field test in Tenerife in summer 2012. DEM generation will be followed by automatic global path planning and the manual definition of global waypoints. At present the PRoViScout team is assessing methods for the fusion between rover-based and aerobot images in order to automatically localize the rover in the global map.

Acknowledgements

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