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Science requirements for PRoViScout, a robotics vision system for planetary exploration

E. Hauber (1), D. Pullan (2), A. Griffiths (3), G. Paar (4)
(1) DLR-Institute of Planetary Research, Berlin, Germany, (2) University of Leicester, UK, (3) UCL, London, UK, (4) Joanneum Research, Graz, Austria (Ernst.Hauber@dlr.de / Fax: +49-30-67055325)

Abstract

The robotic exploration of planetary surfaces, including missions of interest for geobiology (e.g., ExoMars), will be the precursor of human missions within the next few decades. Such exploration will require platforms which are much more self-reliant and capable of exploring long distances with limited ground support in order to advance planetary science objectives in a timely manner. The key to this objective is the development of planetary robotic on-board vision processing systems, which will enable the autonomous on-site selection of scientific and mission-strategic targets, and the access thereto. The EU-funded research project PRoViScout (Planetary Robotics Vision Scout) is designed to develop a unified and generic approach for robotic vision on-board processing, namely the combination of navigation and scientific target selection. Any such system needs to be "trained", i.e. it needs (a) scientific requirements which the system needs to address, and (b) a data base of scientifically representative target scenarios which can be analysed. We present our preliminary list of science requirements, based on previous experience from landed Mars missions.

1. Introduction

On other terrestrial planets (including Mars), orbital data from previous missions are likely to be the only source of contextual information prior to landing although some ground truth (albeit inferred) may be available. Surface missions tend to visit new sites and therefore have to undertake basic site investigation *in situ* with whatever payload assets are available. Although inevitably limited, payloads should include the basic capabilities a human field geologist would consider essential, namely remote to close-up imaging, field analysers to determine rock/soil composition and tools to physically interact with surface materials. In terms of initial reconnaissance, imaging is the most important asset (i.e. PRoViScout). Once the landing site has been characterised, human scientists and/or autonomous systems can then place detailed observations into appropriate context and subsequently make revisions as the mission evolves.

Geological features often appear complex and are influenced by a huge number of variables. In the field, human geologists mentally deconstruct what they see and draw on broader contextual input (the bigger picture) to help classify geological materials and the processes that act on them. Visual observations made in the field, aided by effective use of simple tools such as a hammer and a hand lens, provide an initial vision-based assessment of the local geology. Assessment relies on iteration since features seen from afar often look very different when viewed close up (sometimes unexpectedly so). This emphasises the importance of detailed close-up observations and measurements (payloads must be equipped with appropriate deployable instruments and tools for *in situ* work), and the need for incorporating re-evaluation in the scientific assessment process.

2. Science requirements

Our selection of general scientific requirements for robotic rover vision systems on Mars is based on lessons learned from previous landed missions. Our list is compiled from a geological perspective (a “wish list”), i.e. it is not intended to represent the final list of requirements for the PRoViScout system. Naturally, PRoViScout has to meet a significantly smaller subset of these requirements. For each requirement, the scientific rationale is given together with – where available – an example image of a previous landed mission. The requirements are subdivided into science and performance requirements, and science requirements are further categorized into imaging requirements (for panoramic, 3D and stereo, spectral, microscopic, and aerobot imaging) and geophysical requirements (e.g., for ground penetrating radar). We also list the names of all Mars missions which have observed the respective feature. The requirements have been prioritised for importance of their inclusion to the PRoViScout framework, the priority levels are stated to be 1- high, 2 – intermediate and 3 – low. 3. Below we show examples of requirements for 3D sensors and spectrometers (Table 1).

Table 1: Examples of science requirements for the PRoViScout system (for 3D and multispectral [grey] imagers).

Req. No.	Description	Rationale	Mission	Priority
SR01.001	The system shall be able to identify structural layering in rocks and soils	Information on sedimentary environment and stratigraphy	MER	1
SR02.001	The system shall be able to generate distance maps (e.g., by ToF cameras)	Information on distances (scale as important parameter in geomorphology)	all	1
SF03.001	The system shall be able to determine grain sizes ≥fine sand fraction (i.e. 0.125 mm to 0.25 mm)	Grain sizes are the basis for rock classifications, e.g., of clastic materials (e.g., clay vs. sand)	e.g., MER Opportunity , Phoenix	1
SF03.006	The system shall be able to distinguish clastic and crystalline textures.	Difference between major types of rocks (sediments vs. volcanic)	e.g., MER Spirit	1
SF03.008	The system shall be able to classify the roundness of grains.	Information on transport processes and distances (e.g., positive correlation between roundness and transport distance)	both MER	1
SR02.008	The system shall be able to locate the current position with respect to images taken by the aerobot system	Correlation between lander and lander/rover images (e.g., approach of Opportunity to Endurance Crater)	MER-HiRISE	1
SF04.001	The system shall be able to recognize compositional layering.	Information on changes in the environment (e.g., changes in the mineralogy of aqueous alteration products)	Both MER	1
SF04.002	The system shall be able to identify polymict features (multi-compositional)	Homogeneous or heterogeneous compositions bear information on lithology	all	1

4. Evaluation of test sites

PRoViScout will perform a final field test on a suitable analogue site in summer 2012. Several candidate sites were evaluated for their scientific and technical merits with respect to the project needs (Table 2). In particular, we assessed the characteristics of volcaniclastic rocks in Tenerife (Las Canadas caldera), hyaloclastites in Iceland, and carbonate mounds in Morocco. We use these sites as typical examples for classes of sites: Iceland is a representative of cold environments (another site falling in this category would be Svalbard, which displays unique travertine deposits). Tenerife is a type locality of a volcano-tectonic environment with explosive eruptions and fallout deposits, and SE Morocco displays outcrops that are of high geobiologic interest (travertines, stromatolites, mud mounds). All three sites considered here offer interesting scientific targets. From a rover platform perspective, the important logistical considerations point to Tenerife as the primary choice.

A preparatory field trip to Tenerife in June 2011 explores the area in detail and acquires training data for the system.

Table 2: Criteria used to assess field sites.

Criterion	Tenerife	Iceland	Morocco
Good and stable weather	yes	no	yes
Easy accessibility by car	yes	no	partly
Restrictions to access	partly	no	no
Navigability of terrain	good	good	moderate
Analogue lithology	yes	yes	no
Accessibility of outcrops by rover	yes	good	moderate
Little vegetation cover	yes	yes	yes
Location in Europe	yes	yes	no

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