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PRoViDE: Planetary Robotics Vision Data Processing and Fusion

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Abstract

The international planetary science community has launched, landed and operated dozens of human and robotic missions to the planets and the Moon. They have collected various surface imagery that has only been partially utilized for further scientific purposes. The FP7 project PRoViDE (Planetary Robotics Vision Data Exploitation) has assembled a major portion of the imaging data gathered so far from planetary surface missions into a unique database, bringing them into a spatial context and providing access to a complete set of 3D vision products. The processing chain is exploited by a multi-resolution visualization engine that combines various levels of detail for a seamless and immersive real-time access to dynamically rendered 3D scenes. Latest results of 3D fusion between HiRISE and MER/MSL 3D stereo vision products are shown, as well as combined 3D vision processing results from multiple rover stations such as available for MER at Victoria Crater and for MSL at the Shaler site.

1. PRoViDE Scope & Components

Various planetary surface imagery has only been partially exploited for further scientific application purposes in terms of 3D data extraction, particularly the comprehensive data sets from MER's, Apollo's and Lunokhod's especially with large baselines. The PRoViDE project has collected them in an unique geospatial and temporal manner and compiled 3D vision products in order to enable a comprehensive overview of the existing data. Orbiter imagery covering these sites exist to a sufficient quality that allows a seamless embedding of the surface data. The PRoViDE major building blocks are summarized as follows:

- A **vision data catalogue** to identify candidate planetary imagery to be used for 3D vision processing, covering relevant robotic sites of recent and ongoing missions such as MER and MSL, and Lunar ground-level panoramas.
- **Comprehensive 3D vision processing** of the mentioned planetary surface missions (heritage of PRoVisG [1]), using the images identified in the vision data catalogue.
- Provision of **highest resolution & accuracy remote sensing vision data processing results** for the mentioned mission sites to embed the robotic imagery and its products into spatial planetary context including updating local-to-global transformations to enable all rover imagery to be co-registered to orbital imagery.
- **Seamless integration between orbit and ground vision data** of recent, ongoing and planned missions.
- **Added-value mechanisms** such as shape-from-shading (SFS), and the use of additional unexpected (serendipitous) image combinations (e.g. stereo pairs) leading to a better 3D description of the surface.
- Define, rehearse, execute and evaluate use cases for scientific exploitation of newly generated 3D vision products, their presentation and visualisation.
- Demonstrate the potential of existing and forthcoming planetary surface vision data by **highly realistic real-time visualisation**.
- Disseminate key data & its presentation by means of a **web-based GIS and rendering tool** in order to serve the educational, publicity and scientific objectives of Europe's planetary robotic missions.

2. Orbit-to-Ground Data Fusion

A major PRoViDE aim is the fusion between orbiter and rover image products. This is a great challenge due to the large differences in sensor footprint and ground sampling distance, as well as so far missing context for a geometrically unique presentation. To close the gap between HiRISE imaging resolution (down to 25cm for the OrthoRectified image (ORI), down to 1m for the DTM) and surface vision products, images from multiple HiRISE acquisitions are combined into a super resolution data set [2], improving the Ortho images resolution to 5cm. After texture-based co-registration with these refined orbiter 3D products, MER Pancam and Navcam as well as MSL Navcam and Mastcam 3D image products can be smoothly pasted into a multi-resolution 3D data representation. The refined registration of model height combined with the accurate rover positions based on tracks visible in the super resolution HiRISE images lead to immersive multi scale and multi sensor models. Typical results from the MER and MSL missions are presented by a dedicated real-time rendering tool which is fed by a hierarchical 3D data structure that copes with all involved scales from global planetary scale down to close-up reconstructions in the mm range.

This allows us to explore and analyze the geological characteristics of rock outcrops in larger context, based on combinations of HiRISE and rover fixed stereo base length (Figure 1) or wide base length stereo 3D products(Figure 2). The detailed geometry and internal features of sedimentary rock layers are interactively available to aid paleoenvironmental interpretation. This integrated approach enables more efficient development of geological models of Martian rock outcrops. 3D measurement tools are ready to obtain geospatial data of surface points and distances between them.

For the Lunar case, based on an LRO NAC high resolution DEM (Figure 3), data fusion and artificial 3D-modeling of Lunar surface (Figure 4) have been carried out. It is very useful for search for observation points of Lunokhod panoramic images (Figure 5), and it can be used to model a scenery simulating as being observed by a spacecraft once landed on the Moon [4].

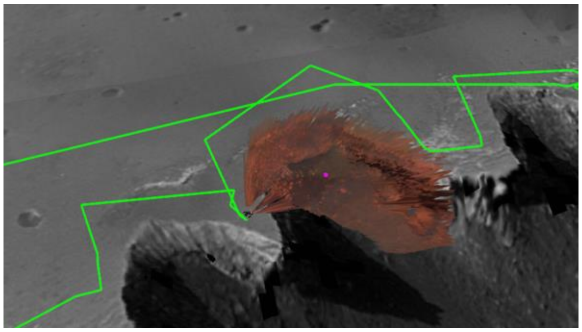

Figure 1: Fusion of HiRISE super resolution with MER fixed base length stereo-derived map

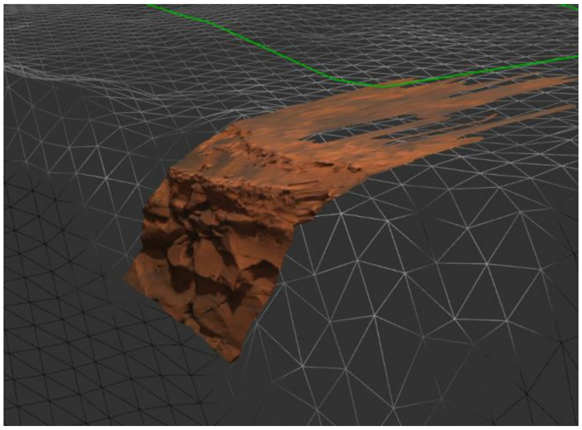

Figure 2: Fusion of HiRISE DTM with MER wide base length stereo-derived map

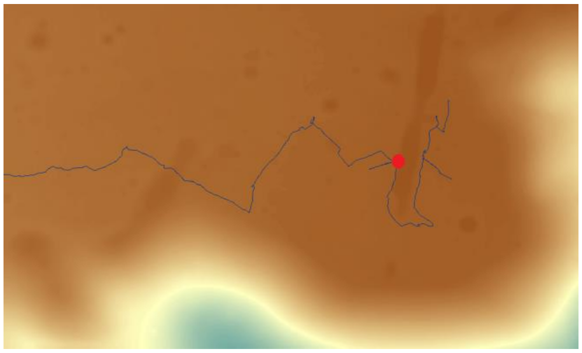

Figure 3: High-resolution DEM produced from LRO NAC photogrammetric image processing

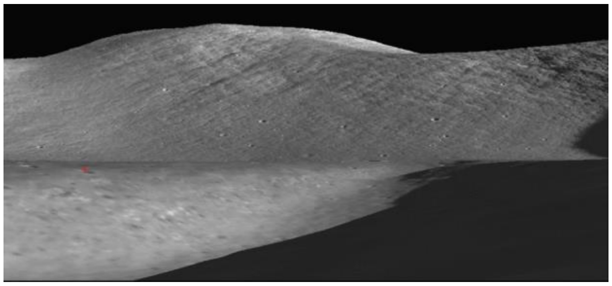

Figure 4: Result of artificial Lunar surface modeling on Lunoknod-2

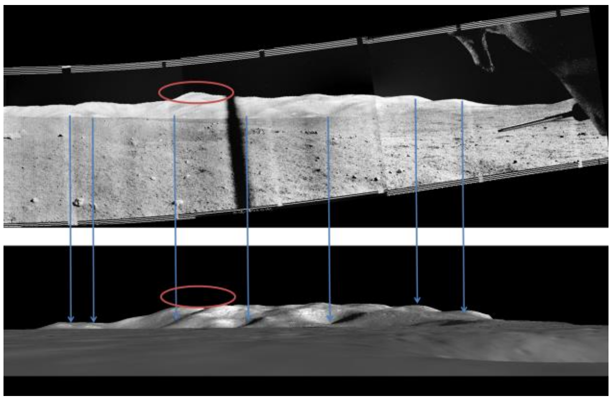

Figure 5: Comparison of the modelled image (below) with the part of processed archive panorama (above). Main features on the horizon can be easily identified. The highest peak and some hills on the left are absent on the modeled image due to the small coverage of the detailed DEM used for modeling (the peak is more than 25 km far from the landing site).

References

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