3D DATA PRODUCTS AND WEB-GIS FOR MARS ROVER MISSIONS FOR SEAMLESS VISUALISATION FROM ORBIT TO GROUND-LEVEL

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ABSTRACT:

Planetary image and 3D data elements collected from past, on-going missions focus on different specific requirements and mostly are treated separately. However, to analyse an area of interest properly or to do any extensive geological classification and interpretation requires 3D information at various level of details. This report will describe a wide range of developments and the processing results achieved within the EU-FP7-PRoVisG project (http://provisg.eu), which was carried out from 2008 to 2012, and the EU-FP7-PRoViDE project (http://provide-space.eu) that started in 2013 for 36 months duration to collect all the multi-view imaging data from ground-level robotic and orbital sensors covering three Mars rover missions (MER-A, MER-B, MSL), and process them into a coherent set of co-registered 3D imaging products. Bringing them into the most accurately possible co-registered unique geospatial context allows exploring them through an interactive real-time visualisation tool and Web GIS.
The work commenced with the automated co-registration of common features in orbital datasets (DTMs and Orthorectified Images) with the surface missions being analysed (MER-1/-2 and MSL). We have processed CTX images to derive orthorectified Images (ORIs) and Digital Terrain Models (DTMs) at (6 metres/pixel) and co-registered these CTX ORI/DTMs with HRSC ORI(12.5m/pixel)/DTM(75m/pixel) which are themselves co-registered with MOLA. Subsequently, HiRISE ORI(0.25m/pixel)/DTMs(1m/pixel) have been co-registered with CTX. The co-registration accuracy achieved is up to the sub pixel level of the finer layer, e.g. 1.25m/pixel for CTX-to-HRSC and 0.6m/pixel for HiRISE-to-CTX. Processing is performed via global least squares fitting based on mutual shape adapted automated tie-points [1]. Secondly, we generate multi-resolution ground level 3D reconstructed products from different instruments onboard the rovers, e.g. MSL MastCam and NavCam, providing resolution from 0.074mrad/pixel to 0.82mrad/pixel. Wide baseline stereo ORI/DTM were then computed from stereo images, i.e. NavCam images, via region growing/ALSC [2] based on intra-stereo and Bundle adjustment for inter-stereo processing. Images from non-stereo cameras (e.g. MSL MAHLI) are then co-registered and ortho-rectified based on NavCam ORI/DTMs. For close range, we are able to produce better than 0.01m/pixel resolution ORI/DTMs (e.g. 0.01m/pixel NavCam, 0.3cm/pixel MastCam-34, and 0.1cm/pixel MastCam-100) at this stage. Finally, we fuse the reconstructed wide baseline ground ORI/DTMs with HiRISE ORI/DTM to bring the high-resolution ground products into a common global context. During this stage, the ground-to-orbit co-registration is performed via combined mutual information/morphological edge extraction method and cross-validated using rover tracks that appeared on different HiRISE images which are similarly co-registered with CTX/HRSC. We therefore updated existing SPICE kernel data with the bundle adjusted rover traverse provided by US collaborators [3]. Employing these SPICE kernels, rover locations and visual fulcra are derived in the global coordinate system. As a start, computation of the fulcra assumes a simple surface of the rover surroundings, which will subsequently be updated applying the derived local DTMs or HiRISE DTMs for further refinement of these field of view footprints.
These digitised multi-resolution 3D ground-level products enable the “virtual geologist” to perform close-up visual analysis of key features (e.g. sedimentary layers) and make measurements (e.g. distance, dip and slope) with the highest possible detail at a high level of accuracy. These will enable scientists to select geologies in an accurately geo-referenced global context and jump into a detailed local view of a 3D scene. These 3D products can further be used for applications with wider scientific interest given the capability of multiple levels of resolution and global reach. Exemplarily the data is inserted into our interactive Web-GIS system, i.e. PRoGIS (http://progisweb.eu) being developed in PRoVisG and upgraded within the scope of PRoViDE by the University of Nottingham in collaboration with UCL-MSSL.
The PRoGIS system is developed based on OGC protocols to provide visual and database search mechanisms for the display of stereo rover frames on a raster backdrop formed by co-registered multi-level orbital ORIs. The public will gain access to the Mars rover mission data (via UCL-MSSL’s PDS mirror) and our seamlessly interconnected products within the unique geographical context. Additionally, PRoGIS also provides the interactive photogrammetric operations, which are powered by the PRoViP (Planetary Robotics Vision Processing) system developed in PRoVisG, to initiate better understanding of the surface for expert users. PRoGIS will serve the educational, publicity and scientific objectives of our research.

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In addition, the 3D products can also be directly and interactively explored and scientifically analysed using the 3D viewer being developed by VRVis, a collaborator of the PRoViDE project. It applies advanced real-time rendering methods to enable smooth navigation through 3D reconstruction of planetary terrains. A high degree of realism is important to allow geological assessments. To achieve this goal, physical properties of rock material are considered for rendering. Different Bidirectional Reflectance Distribution Functions (BRDFs) are estimated from source images and implemented as “shaders” that directly run on a Graphical Processing Unit (GPU) and hence in real/time at MSSL. Besides changing material properties, natural illumination of the reconstructed scene is also important for a realistic impression. Skylight irradiance models from Mars and Earth will be applied for that purpose. A scientist can switch between both models and see how rock surfaces from Mars would appear on Earth enhancing scientific analysis potential. These skylight models simulate not only the light from the sun for both planets but also the atmospheric scattering of light. The 3D viewer is a valuable additional tool for scientific analysis of planetary terrains and also serves as a planning tool for operations.

In future, further SPICE kernel updates will be derived to be consistent with all datasets from orbit to ground-level.

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