Application of PRo3D to Quantitative Analysis of Stereo-Imagery Collected During the Mars Utah Rover Field Investigation (MURFI) Analogue Rover Trials

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APPLICATION OF PRo3D TO QUANTITATIVE ANALYSIS OF STEREO-IMAGERY COLLECTED DURING THE MARS UTAH ROVER FIELD INVESTIGATION (MURFI) ANALOGUE ROVER TRIALS.

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Introduction: A major component of the payload for NASA's Mars Exploration Rovers, Mars Science Laboratory as well as the upcoming ESA ExoMars 2020 Rover, and NASA Mars 2020 Rover are the panoramic digital stereo-cameras (Pancam, Mastcam, PanCam, Navcam). These are primarily used for imaging rock outcrops along rover traverses in order to characterise their geology. A key focus is on sedimentary rocks that have the potential to contain evidence for ancient life on Mars. Clues to determine ancient sedimentary environments are preserved in sedimentary bedding geometries, sedimentary structures and grain textures and dimensions. The panoramic camera systems take stereo images which are co-registered to create 3D point clouds of rock outcrops to be quantitatively analysed [1].

The Mars Utah Rover Field Investigation (MURFI 2016) is a Mars Rover field analogue mission run by the UK Space Agency (UKSA) in collaboration with the Canadian Space Agency (CSA). MURFI 2016 took place between 22nd October and 13th November 2016 and consisted of a science team based in Harwell, UK, and a field team including an instrumented Rover platform at the field site near Hanksville (Utah, USA) [2]. The Aberystwyth University PanCam Emulator 3 (AUPE3) camera system [3, 4] was used to collect stereo panoramas of the terrain the rover encountered during the field trials, in order to aid rover traverse and science target decision making as well as geological analysis.

AUPE3: AUPE3 was developed to enable field deployment and testing of a PanCam-like instrument during the development and manufacture of the flight model, to enable development of data processing pipelines, scientific operations and calibration routines. The AUPE3 system emulates the technical specifications of the PanCam instrument using commercial components [4]. It consists of two Wide Angle Cameras (WAC) separated by 50 cm and with a field of view of 38.3°, enabling the construction of Digital Terrain Models with horizontal resolutions of 2 mm within 4 m, and 10 mm up to 10 m away from the rover and a vertical resolution of 1 mm.

PRo3D: Development of processing and visualisation software for Martian rover-derived stereo-imagery has taken place as part of the EU-FP7 PRoViDE project [5]. Stereo-imagery processed in PRoViP is rendered as Ordered Point Clouds (OPCs) in PRo3D (Fig. 1), enabling the user to zoom, rotate and translate the 3D outcrop model. Interpretations can be digitised directly onto the 3D surface, and simple measurements can be taken of the dimensions of the outcrop and sedimentary features, including grain size. Dip and strike of bedding planes and fractures is calculated within PRo3D from mapped bedding contacts and fracture traces. The View Planner function also allows for interactive visualisation of potential imaging targets. Validation of the data and tools in PRo3D is ongoing as part of a UKSA funded project for use on the ExoMars and Mars 2020 rover missions.

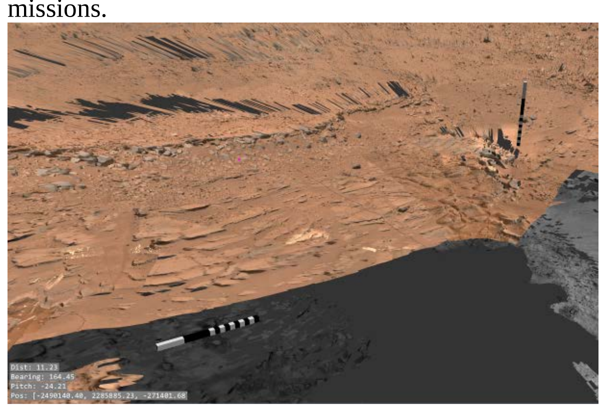

Figure 1. Merged 3D model of the Shaler outcrop, encountered on the MSL mission, and rendered in PRo3D. Scale bars are 2 m.

MURFI analogue field trials: The area of operations for the MURFI trials was in the Utah desert, ~12 km outside of Hanksville. The regional geology and remoteness of the area makes it an excellent location for this purpose. An 'ExoMars-like mission' was conducted over 9 'sols' with a blind science team based in Harwell, UK, and a field team to operate and monitor rover activities, as well as survey the local geology for validation of the science team's observations.

Data collection: During the analogue mission itself, the AUPE3 unit was mounted onto the rover mast, at a height of 1.6 m. Mono and stereo panoramas were collected at each rover location. Handheld GPS readings (2-3 m accuracy) and compass bearings were taken at each imaging location (out-of-simulation) for post-processing of the data. 16 stereo-datasets were collected as part of the MURFI mission. Additional out-of-simulation data was collected in the Hanksville-Burpee Quarry, ~ 4 km to the north of the area of operations, for the purpose of further development of PRo3D and validation of the 3D datasets. This data was collected with the AUPE3 unit mounted on top of a tripod at a height of 2 m, in order to more closely emulate the geometry of the ExoMars 2020 PanCam. Stereo panoramas were processed using an automated pipeline, using data transfer through an ftp server provided by Joanneum Research, with a turnaround time of a typical full panorama in the range of half an hour (from upload of panorama images including meta data to availability of the visualization-ready OPCs).

3D data analysis: PRo3D provides an immersive environment for visualisation and analysis of the stereo data collected during the MURFI trials. Features of interest in the area could be annotated, and marked as such. Distances between the rover position and a feature of interest can be measured to aid prioritisation of science targeting. Where grains or rocks are present and visible, their dimensions can be measured (Fig. 2).

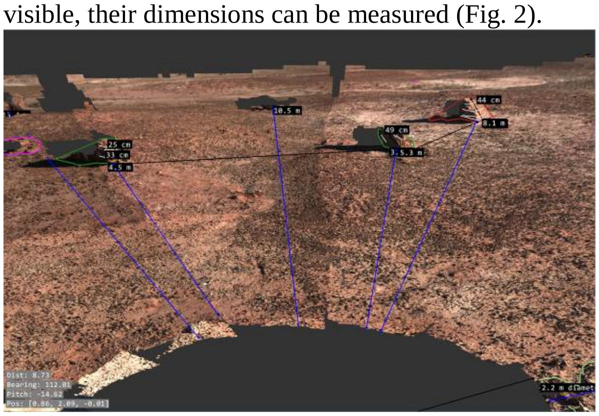

Figure 2. Annotated OPC of the post-drive panorama taken on Sol 1 of the MURFI mission. Annotations made in PRo3D indicate the distance of regions of interest from the rover position.

The Hanskville-Burpee quarry contained well-preserved outcrops. Stereo imagery of 5 of the outcrops was collected together with an Unmanned Aerial Vehicle (UAV) derived Digital Terrain model and orthoimagery of the area. This data was used for outcrop interpretation, and further development of PRo3D (Fig. 3). A coarsening-up succession was identified with a red, well-layered mudstone at the base of the outcrop, above a coarse, cross-bedded sandstone. This is overlain by a medium-coarse, finely cross-laminated sandstone, and that by a granular to pebbly cross-laminated sandstone.

The irregular thickness of each stratigraphic unit, together with the grain size data, cross-beds/laminations and other observations, such as a pebble lag at the base of the upper unit are observations that are used to interpret the sedimentary processes and environment.

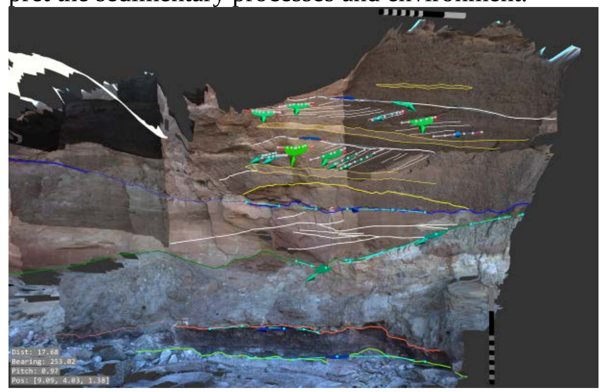

Figure 3. Interpreted OPC of an outcrop at the Hanksville-Burpee Quarry, showing the locations of stratigraphic boundaries, line interpretations of sedimentary structures and dip and strike measurements. Scale bars are 2 m.

Future work: A focus for future development of Pro3D in preparation for application to the ExoMars 2020 and NASA 2020 missions is validation of the data and meaurements taken using Pro3D. Collection of in situ field data by a human geologist allows for direct comparison of viewer-derived measurements with those taken in the field. Georeferencing of the OPC datasets will also take place, assessing the quality of the Mission Operation Team's remote rover localization, rover Inertial Moment Unit (IMU) localization, and GPS data. This will also aid in merging of rover-derived imagery with UAV and orbital datasets, to build semi-regional multi-resolution 3D models of the area of operations for immersive analysis and contextual understanding.

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