VALIDATION OF THE 3D VISION AND VISUALIZATION FRAMEWORKS PROVIP AND PRO3D FOR THE MARS2020 AND EXOMARS STEREO PANORAMIC CAMERA SYSTEMS.

Gerhard Paar[1], Robert Barnes[2], Sanjeev Gupta[2], Christoph Traxler[3], Matt Gunn[4], Christian Koeberl[5]. [1]Joanneum Research, Graz, Austria; [2]Imperial College London, United Kingdom; [3]VRVis Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH, Vienna, Austria; [4]Aberystwyth University, United Kingdom; [5]Natural History Museum, Vienna, Austria, and Department of Lithospheric Research, University of Vienna, Austria (christian.koeberl@univie.ac.at).

Introduction & Rationale: Planetary rover missions use panoramic stereo camera systems to image rock outcrops along rover traverses, in order to characterize their geological history and focus the search for ancient biosignatures. Stereo imaging from the ExoMars PanCam instrument will significantly enhance the ability of the science team to investigate terrain and geology through 3-D vision [1]. The Mars 2020 rover will also carry a Panoramic Camera System (Mastcam-Z [3]) to obtain multi-spectral stereoscopic panoramic images with a 3.6:1 zoom capability and a matched pair of zoom CCD cameras that each provides broad-band red/green/blue (RGB), narrow-band visible/near-infrared (VNIR) color with 5° to 15° fields of view.

Both instruments, by exploiting their 3D vision capabilities from which the stratigraphy, sedimentary architecture, impact cratering history, and paleoenvironmental information can be reconstructed from Digital Outcrop Models (DOMs): grain size where visible; layer geometries; quantitative character of sedimentary structures and cross-bedding orientations from which palaeoflow can be calculated [4][5]; sedimentary structure dimensions. These data assist in the robust interpretation of sedimentary facies for paleoenvironmental reconstruction. A main target is also the detection and understanding of impact breccias, shatter cones, and other materials of impact origin. The rapid collection of these data greatly facilitates the full scientific exploitation of image data collected by Martian rovers, providing vital context for planning of rover science operations, as well as for analysis of scientific results.

The validation of the tools that enable such analysis is an important prerequisite for scientific soundness of any investigation building on the data and data assessment tools. We report on our plans and preparation works for the respective validation procedures.

3D Vision Processing: The processing framework ***PRoViP*** (Planetary Robotic Vision Processing [2]) provides a versatile workflow to generate 3D vision processing products out of stereoscopic images as present from PanCam, Mastcam-Z and other past and present planetary imaging sensors from Rover missions (MER, MSL), such as:

a) Digital Elevation Models
b) Ortho images
c) 3D meshes, superimposed with texture
d) Derived thematic maps of the surrounding describing reconstruction accuracy, occlusions, solar illumination, slopes, roughness, hazards etc.

Visualization: The interactive 3D viewing tool ***PRo3D*** [4] allows virtual exploration of reconstructed Martian terrain and geologic analysis of 3D datasets. It provides measurement and annotation tools (Fig.1) to:

a) Delineate geological boundaries
b) Obtain dimensions of geologic features
c) Obtain linear and projected distances between surface points
d) Calculate dip and strike of stratigraphic layers
e) Interpret DOMs' geological features.

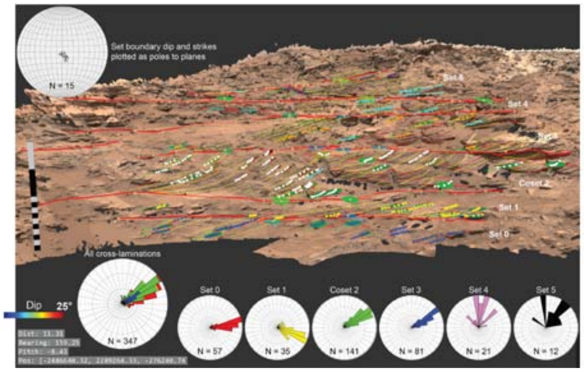

Figure 1: The MSL Williams outcrop (Sol 1087) digital outcrop model (DOM) in PRo3D with interpreted set boundaries (thick red lines) and a subset of the measured dip and strikes (dotted lines with colored disks, the small red line indicates strike direction) shown to avoid obscuring the outcrop details. Lamination contacts have been mapped onto the DOM and can be seen to shallow in inclination in Sets 4 and 5. Equal distance rose diagrams with 10° bins are inset into the DOM, showing unimodal NE dip directions for Sets 0 to 3 and a more polymodal N dip direction for Sets 4 and 5. The poles to planes of the set boundaries have been plotted and show a general NW dip direction. Scale bar is 2 m. See [5] for more details.

Validation logic: PRoViP and PRo3D are a consistent bundle, therefore all end-to-end validation is done directly in PRo3D and its available data assessment capabilities with following logic:

a) Define elements of validation as relevant for DOM analysis being equivalent to field observations: The initial primary concern is the geometry of the processed Ordered Point Cloud (OPC) surfaces, adherence to true geometry at an optimum imaging distance, and how this geometry varies with distance and distance:baseline ratio.

We are particularly interested in how any changes in geometry will affect key measurements, particularly vertical and lateral dimensions and layer dip and strike. Field validation also lets us gain a greater understanding as to what details we are likely to miss when just interpreting geology from panoramas and DOMs.

b) Acquire representative data in the field using instrument-analogue gear (in a geometric sense)
c) Acquire conventional state-of-art reference measurements & observations of the scene
d) Geometrically calibrate the instrument-analogue gear using the same methods as planned for the actual flight instrument
e) Process the acquired image data based on this geometric calibration and convert it to the PRo3D compatible 3D data structure
f) Perform a DOM analysis within PRo3D
g) Compare the DOM analysis results with those performed using the conventional methods
h) Further purely geometric measures have to be evaluated such as local noise measures, completeness, influence of interpolated data, sharpness on edges, occlusions behavior, resolution on fine structures including connectivity, level of outliers, subpixel histogram distribution in disparities, robustness against linearization imprecision, and many more – to be compared with the theoretical stereo instrument’s 3D vision performance derived from its geometric capabilities, done in a laboratory environment and using reference sensors having an additional level of accuracy & resolution compared to the instrument under investigation.
i) In later stages, an evaluation has to be added that shows the dependency and robustness against calibration deviations (from mechanical or thermal influences), image artefacts, dust cover of lenses, treatment of data borders and holes between 2D and 3D patches, including the assessment of value from using wide-baseline stereo with images captured from different rover positions. Further dependencies such as the effect of using different or a combination of spectral bands for stereo processing will be tackled.

Status of validation: The first stages of the validation process took place at Brimham Rocks [5], Yorkshire, UK, in July and August 2017. Three outcrops of spectacular fluvial cross-bedded sandstones were imaged extensively using the Aberystwyth University PanCam Emulator (AUPE) [6]. 32 image datasets were collected, typically at incremental distances from the chosen outcrop – at 2, 4, 8 and 16 m, with wide baseline images (lateral movement of the camera by 1 m) also collected at 8 and 16 m away from the outcrop. Several PanCam HRC (High Resolution Camera) tiles and panoramas were collected as well. Reference measurements were collected after imaging, for comparison to those taken from the processed OPCs in PRo3D (Fig. 2). These included general scale, bedset thicknesses, layer thicknesses, grain size and variation, as well as the dip and strike of layers, foresets, set boundaries and cross beds. Future work with this data will involve fully geo-registering the image data collected, to ensure that field measurements can be directly compared, processing wide baseline stereo, and perfection of geometric calibration and radiometric color blending techniques.

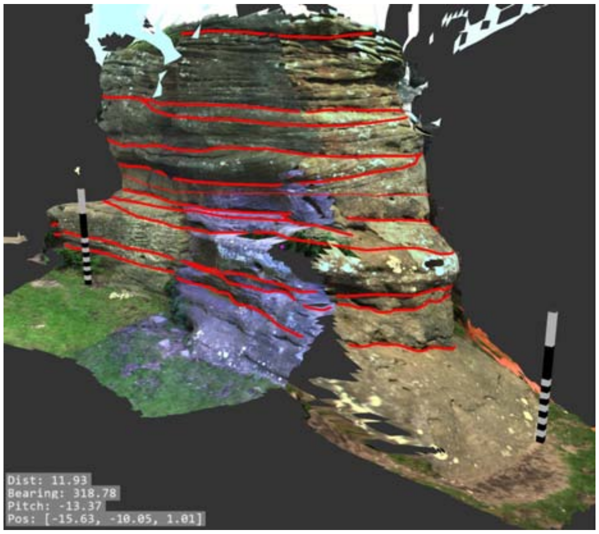

Figure 2: Two OPCs collected from AUPE images of Eagle Rock, at Brimham Rocks, UK merged together. The location of set boundaries has been mapped onto the OPC surface based on the geometry of the internal layers, and measurement of dip and strike as well as the thickness of layers and sets of cross-beds will be carried out when the data has been georeferenced. Scale bars are 2 m.

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