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Immersive Visualization of Planetary Reconstructions for Geological Interpretation

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Abstract

In this paper, we describe how remote geological analysis of planetary surfaces can benefit from immersive virtual reality visualization and interaction. An extension of the PRo3D Viewer [1] (http://pro3d.space) allows planetary scientists as well as a non-expert audience to immersive themselves in a virtual, true-to-scale Martian environment.

1. Introduction

For planetary science, geology and particularly sedimentology are crucial to uncover the processes responsible for forming the present-day surface of a planet. Traditionally, geologists base their analyses on measurements and observations they collect in the field. Consequently, in the context of exploring the geology of Mars, they are limited to directly inspecting rover images or using 3D reconstructions derived from photogrammetry.

Although the interactive rendering of 3D reconstructions gives users a much better impression of scale and depth than 2D images can provide, the output is still confined to a rather small and flat computer screen. The loss of scale and depth perception typically is mitigated by using scalebars and 3D navigation, which is satisfying to both expert and public audiences. However, to use these interactions effectively requires training and true immersion cannot be achieved.

Therefore, this work strives to create an immersive 3D depiction of the Martian surface, which experts and laypersons can navigate in and interact with in a natural way. At the time of writing, the described work is ongoing. Therefore, after briefly outlining the data pipeline, we describe existing and planned features and we conclude with the reception of our work so far.

2. Reconstructions from Imagery

The processing framework PRoViP (Planetary Robotic Vision Processing) [2] provides a versatile workflow to generate 3D vision processing products out of stereoscopic images as designed to be obtained from ExoMars PanCam, Mars 2020 Mastcam-Z and other past and present planetary imaging sensors from Rover missions (MER, MSL), such as:

a) Digital Elevation Models

b) Ortho images in various filter wavelengths

c) 3D meshes, superimposed with textures

d) Derived thematic maps of the surroundings describing reconstruction accuracy, occlusions, solar illumination, slopes, roughness, hazards etc.

These data products are made available to the further PRo3D workflow in the geographical coordinate system context of the respective planetary body (e.g. Mars), via an optimized hierarchical data structure (OPC – Ordered Point Cloud) [3].

3. PRo3D Existing VR Features

Our current implementation supports the HTC VIVE head-mounted display with two VIVE controllers. We render the processed 3D digital outcrop models (DOMs) at their highest resolution in their true scale. Therefore, when users walk one meter in the real world they also cover one meter of the virtual surface. Since most Martian outcrops are very flat we raise them to about 50cm above ground, otherwise users would have to kneel to inspect surface details. So far, we prepared scenes with DOMs of Garden City and Yellowknife Bay, which are sites of the MSL mission.

While the true-to-scale stereoscopic rendering of DOMs gives users a great sense of the dimensions of the whole outcrop, we also added a virtual tape measure to investigate surface details such as rocks or sediment layers. When holding down the triggers of the controllers, a line appears connecting them with a text label on top showing the current distance. The accuracy of the tracking allows the user to measure distances down to mm scale. Due to walking and head tracking for the navigation and the simplicity of the virtual tape measure geologists, as well as laypersons could naturally navigate the virtual scene and take measurements.

Figure 1: Robert Barnes measuring bedding thicknesses in PRo3D VR in Yellowknife Bay

4. Planned VR Features

With walking as our only mode of navigation, the area of exploration is limited to about 4x4m according to the VIVE specification. Currently we are working on two additional navigation interactions: As common to many VR environments, we will support a teleport interaction, which allows the users to jump to a point they target on the surface. Second, by using the two controllers, users shall be able to scale and rotate the scene arbitrarily including reset mechanisms for true scale and horizon levelling.

We also plan to extend our measurement interactions by using the tape measure to create polylines for delineation of bedding contacts. Since dip-and-strike measurements are essential to geological analysis [4][5], we plan to use the pose information of one controller to orient a plane in 3D and use the distance to the second controller to specify the size of this plane.

5. Conclusion & Outlook

We started the development of the PRo3D VR extension only recently. However, our preliminary results were already tested at a dedicated workshop, involving geologists, planetary scientists, and people from other fields. We complemented these tests by in-depth sessions with planetary geologists to gather additional feedback on the user patterns and efficiency gain. In general, PRo3D VR was well received and the feedback gathered led us to the extensions described in Section 4. Even the geologists, although trained in the interpretation of DOMs, were amazed by experiencing outcrops in their true scale.

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