Master Thesis Proposal: Interactive Correlation Panels for the Geological Mapping of the Martian Surface

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1 Motivation & Problem Statement

The question whether there is, or was, life on Mars has occupied planetary researchers since the dawn of the space age. While recent missions to Mars had the goal to find water on Mars, the upcoming missions ExoMars [ESA16] and Mars2020 [NAS18] have the explicit objective of finding past or present signs of life.

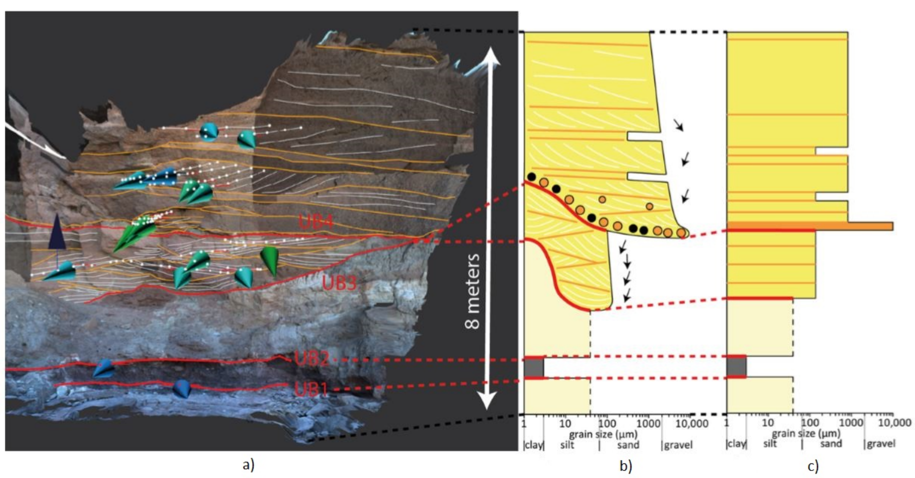

Figure 1: Geological annotations on a 3D surface (a), log (b), and suggestion for a semi-automatically generated log (c) drawn by an expert user.

The central science to finding signs of life, so called biosignatures, is geology. In the case of structural geology, the scientists analyse sedimentary layers in exposed rock faces to understand the history of the planetary surface. Where the actual site of exploration is hard to access, geologists have to rely on digitally annotating and interpreting 3D models of so called rock-outcrops, as seen in Figure 1.a. In case of Mars, these models are photogrammetrically reconstructed from images taken by either orbiter or rover cameras.

From these digital annotations of an outcrop, geologists derive a log, which contains a detailed visual description of the geological layers, shown in Figure 1.b. Multiple logs from multiple outcrops are combined and recurrent surfaces are correlated to form a so-called correlation panel which represents an information-rich geological summary of the analysed area. Geologists create correlation panels typically after the analysis stage. Due to individual preferences this is done manually either by using 2D graphics software, such as Adobe Illustrator, or by relying on completely hand-drawn approaches.

The separation of drawing annotations and creating static correlation panels leads to a very rigid workflow. When geologists draw the correlation panel, they often realize they have insufficient annotation data and need to go back to analysing the 3D models, which in turn requires them to rearrange and redraw their correlation panel.

2 Aim of the Work

The separation of the annotation stage and the interpretation stage (creating correlations) is an artificial one and is founded in the separation of tools, rather than in the actual workflow. Therefore, I propose to integrate semi-automatically drawn, interactive correlation panels into PRo3D, an existing and well-established 3D visualisation and annotation tool [TOH+18]. I claim that an integrated correlation panel, that grows dynamically during the annotation stage, and the resulting feedback cycle greatly improves interpretation speeds and error corrections for remote structural geology.

Such an approach is in high demand by planetary geologists and will also find application in analysis of terrestrial outcrops. The idea was developed together with geologists from the Imperial College of London, and a suggestion what automatically generated logs and correlation panels might look like can be seen in Figure 1.c.

Although logs are 2D, they are based on annotations on the 3D surface, defining a spatial relationship between log and 3D surface. Therefore, a central point of my thesis will be to manage and exploit this 2D-3D relationship. For instance, I will investigate how to draw 3D logs intuitively or how to locate 3D layers in the correlation panel and vice-versa which is a typical challenge in such integrated applications, as discussed by Ortner et. al. [OSP+16]. Another challenge is to provide geologists with an intuitive way to semantically annotate the Martian surface. This is crucial to semi-automatically constructing logs and correlation panels, since the annotations themselves do not have sufficient inherent meaning.

3 Methodology

To get a detailed picture of the state-of-the-art, I will analyse similar tools and review the relevant literature, consisting of geological papers and papers specific to the Mars programmes. The core of this thesis will be a design-study following the guidelines presented in Sedlmair et. al. [SMM12].

After creating a base implementation, I will use an iterative user-driven design approach for further development. At the end of each iteration, I will gather expert feedback by leading planetary geologists to enhance the visual representations and interactions. Additionally to the expert user feedback, I will compare the generated logs to already existing hand-drawn logs for a given dataset for continuous validation.

4 State-of-the-Art

Several tools exist that are used for the visualisation and interpretation of structural geological data [VRG17] [Arc18] [Nor18]. However, none of them provide the degree of integration and interactivity that this work will add to PRo3D. There are tools, mainly from the fields of oil and mining [Lim18], which are capable of creating correlation panels completely automatically, however these operate on information rich, and simply structured data collected from well drilling sites. Besides being very expensive software, these approaches are not usable with outcrop annotation data. Within the range of software for structural geology (no drilling) PRo3D [TOH+18] can be used to display, annotate, and measure 3D surface data. It competes with Lime [Nor18] and VRGS [VRG17] which have limited ways of displaying logs, far away from the envisioned interactive correlation panels.

5 Relevance to the Curriculum of Computer Vision

The courses listed below are part of the curriculum of Computer Vision and relevant to the proposed thesis.

188.305	Informationsvisualisierung VO
188.308	Informationsvisualisierung UE
186.826	Farbe VO
186.827	Visualisierung 1 VU
186.833	Visualisierung 2 VU
186.191	Echtzeit-Visualisierung VU
186.140	Echtzeitgraphik VU
186.101	Rendering VU

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