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High Resolution Digital Terrain Model for the Landing Site of the Rosalind Franklin (ExoMars) Rover

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1. Introduction

The ExoMars Platform and the "Rosalind Franklin" rover of the European Space Agency and of Roskosmos are planned to land in the Oxia Planum on planet Mars in 2021 to search for possible chemical bio-signatures [1, 2]. A safe landing and detailed scientific assessment of the landing site both require accurate knowledge of the local topography. To reconstruct the topography, we generate a Digital Terrain Model (DTM) of the landing site using our novel reconstruction method [3, 4]. The resulting DTM exhibits significant improvement over stereo algorithms such as the Ames Stereo Pipeline [5] and SOCET SET® [6], which suffer from artifacts reducing the resolution and quality of the derived DTM. Stereo algorithms may produce artifacts in areas poor in texture resulting from inaccurate pixel matching, and tend to generate stair-like structures termed pixel locking [7]. The Shape from Shading (SfS, also termed 2D-photoclinometry) method is able to remove these artifacts and increase the DTM resolution significantly, especially when used as a complement to other techniques. Our algorithm combines initial stereo surface estimation and further refinement by SfS. The SfS method relies on a physical model which describes the reflectance properties and employs an in-situ atmospheric parameter estimation that comes with the advantage that external atmospheric measurements are not needed. The method is applied to HiRISE images to successively cover the planned landing site of the Rosalind Franklin rover and yields an effective resolution of 0.25-0.3 m/pixel. Moreover, if no stereo coverage is available in some place, the method can generate DTMs from CTX data which serve as an alternative initial constraint for HiRISE SfS reconstruction and therefore enable greater coverage.

2. Related Work

Shape from Shading uses reflectance images and information about the reflectance properties to estimate the 3D shape of a surface. In the case of planetary remote sensing, orbiters acquire the reflected radiance, and reflectance models such as [8] describe the planetary reflectance properties. Previous SfS approaches have successfully proven to work for the lunar [9-11] and the Martian surface [12-15]. SfS allows for an accurate estimation of surface slopes even in texture-less areas and the reconstruction of the smallest details resolved in the image data. However, a low-frequency constraint is needed for proper initialization which can come from laser altimetry measurements, photogrammetric reconstruction or a coarser SfS DTM. Because Mars is surrounded by a thin atmosphere, recent works have also addressed atmospheric modeling [12, 15].

3. Methods

Our method extends the previous approach of [9, 10] by introducing an atmospheric model to account for the thin but non-negligible atmosphere of Mars [3, 4]. The resulting method has been applied successfully to and validated with CTX imagery [4] and has also been shown to work well with HiRISE imagery [3]. The method comprises three steps: (1) Stereo DTMs previously generated from HiRISE images using the SOCET SET® framework [6] serve as an initialization. (2) Atmospheric parameters are estimated based on the initial DTMs and calibrated HiRISE radiance images. (3) The SfS-based algorithm [9, 10] is applied with combined reflectance and atmospheric modeling [4].

The landing site is covered by several HiRISE images which are used for DTM generation. Due to the large volume of image data, one HiRISE image is cut into a set of partly overlapping regions which are processed in parallel for speedup. The resulting DTMs are stitched together to obtain the final DTM. Some HiRISE images in the landing ellipse do not have a suitable stereo partner, such that no stereo DTMs of these areas exist. To achieve greater coverage, CTX images are planned to be used for calculating a refined initial DTM with our algorithm where HiRISE stereo is not available.

4. Results and Ongoing Work

Figure 1 shows the full DTM of HiRISE image ESP_037558_1985 near the center of the landing ellipse, and Figure 2 contains many small-scale details such as dune ripples inside craters and rough bedrock. Currently, we process more images to achieve greater coverage of the landing site.

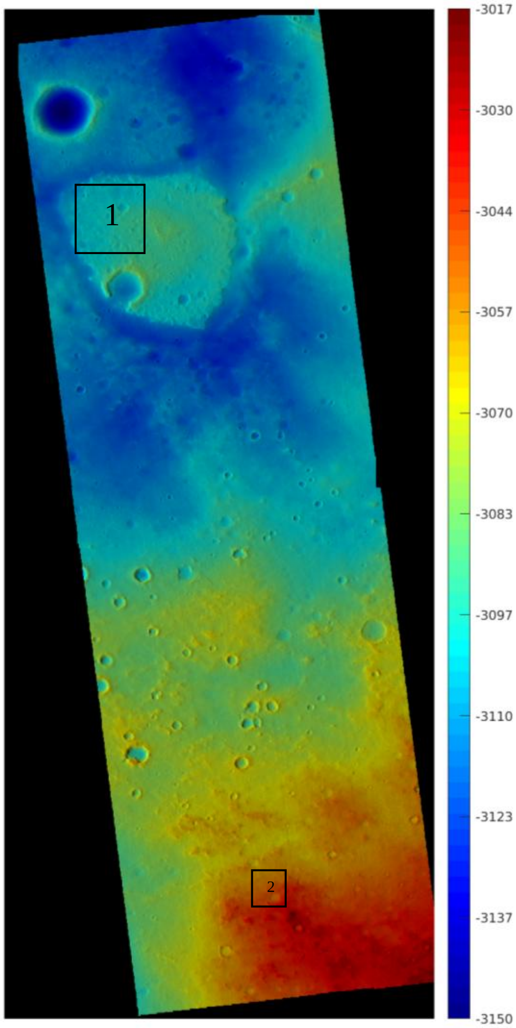

Figure 1. DTM of HiRISE image ESP_037558_1985.

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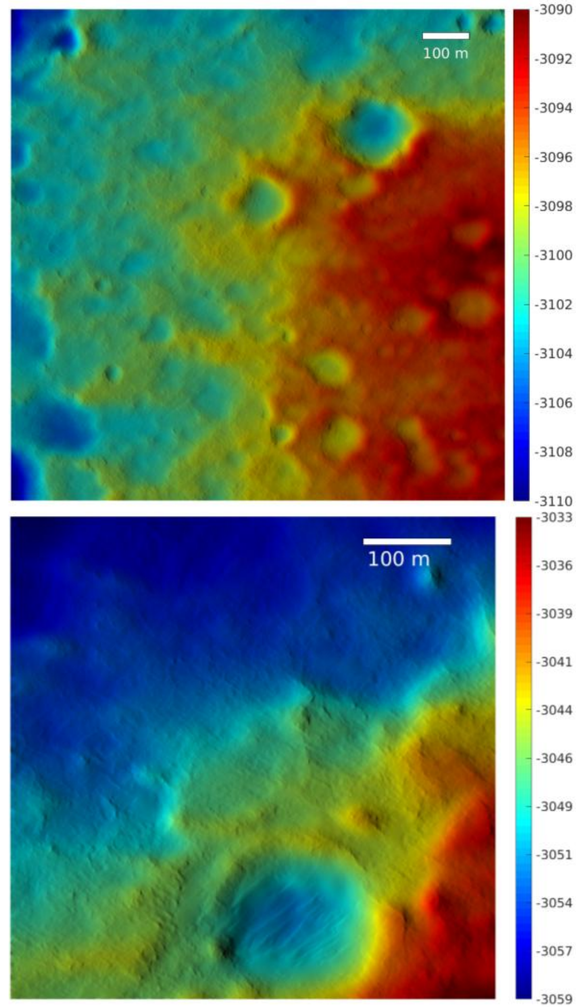

Figure 2. Small-scale details in Oxia Planum. Top: Capping unit (1), Bottom: Dune ripples inside crater (2).

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