A machine vision toolkit for MSL imagery: Demonstration using PIO pictures

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Introduction: Hundreds of new images are being captured since the beginning of August 2012 by the 3 cameras (MastCam, NavCam, HazCam) onboard the NASA MSL *Curiosity* each day. A subset of these has been published on the NASA Public Information Office (PIO) website. We therefore have an opportunity to observe complex geologies on Mars, such as the sedimentary layers and rocks in which the processes of erosion from the wind, water, heat, and volcano eruptions have left their footprint behind. The 100-millimeter focal length MastCam has three times better resolution than the PanCam on the Mars Exploration Rover (MER), which enabled scientists to study the geological processes which have occurred in a given area with the best ever available pictures.

Identifying the sedimentary layer boundaries as well as detecting and counting the number of sedimentary layers and rocks are important techniques for exploration of the planet due to the large amount of information which can be further derived as to their origins. We demonstrate here with the help of computer vision algorithms, how we may be able to collect and analyze key marker information about a particular scene from MSL imagery using limited resources. This will not only aid the field geologists in their interpretation but possibly be applicable in the future to the selection of science targets by onboard rover computers.

Layer Detection: The study area selected is not far from the position of *Curiosity* on Sol 60, where tens of linear layers appear to be present all of which have been affected by different erosion over time. The layers are not all completely linear but appear to join each other if traced horizontally.

But how do we detect layers automatically and with a high degree of reliability? Linear layers are defined to be those layers whose boundaries are distinguishable by intensity edges. They are long, thin, coherent, and traceable features. We start the process with morphological and Gaussian smoothing to enhance the high intensity gradient and connect them into edges. [1] Then we apply a combined Sobel edge detection and morphological gradient detection followed by an adaptive thresholding process. The detected lines are then binarized, filtered by connected component checking, and skeletonized for analysis of their direction and length.

Figure 1 is a portion of a larger image taken by *Curiosity's* 100-mm focal length Mast Camera on Sol 17, showing the base of Mount Sharp, the rover's eventual science destination. The detected layers are labeled in red color; the toolkit also provides the length in pixels and directions for further analysis.

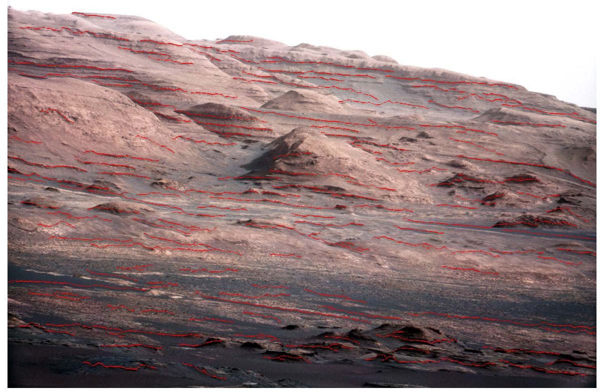

Figure 1. Automatically detected layers labeled in red for a portion of the MSL MastCam PIO Image on Sol 17 (0017MR0050002000I1_DXXX)

Rock Detection: Automated rock detection is another important technique for geological analysis. By automatically detecting the rocks, rovers can effectively find a navigable path after surveying an area. Similar to the sedimentary layers, rocks also reveal a huge amount of geologically interesting information including different strengths of wind erosion and the different sized particles with different strengths of cementing agents.

The Layer and Rock Detection toolkit implements the Graph Cuts based image segmentation algorithm to iteratively define the object (rock) pixels and background pixels [2]. If the stereo left/right images are available, the results can be further optimized with 3D reconstruction [3] once the original data are released on NASA PDS.

Figure 2 shows the image from the same MastCam taken on Sol 51, looking to the “south” towards the central peak of Mt Sharp showing a landscape of assorted rocks which are probably of volcanic origin scattered around on the surface. The detected rocks are labeled with a green color.

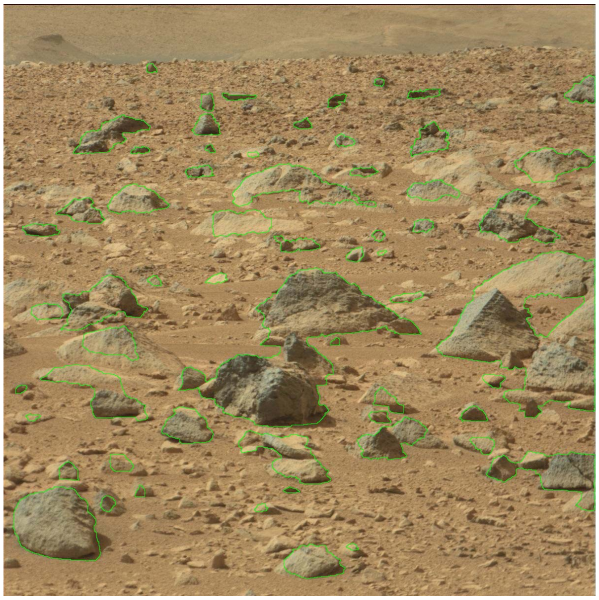

Figure 2 Detected Rocks labeled in green for part of MSL MastCam PIO Image on Sol 51 (0051MR0231035000E1_DXXX)

Conclusions and Future Work: The Layer and Rock Detection toolkit (LRD-STK) is written in C++. It has initially been developed for PIO pictures from the MSL MastCam at Mullard Space Science Laboratory (MSSL) in University College London (UCL). It uses the cross-platform QtSDK for easy installation on a different target system. It has also been integrated into PRoViP, which is the core software processing engine in the EU-PRoVisG project for MER image processing (http://provisg.eu).

These tools will be extended to 3D once MSL data is released on the PDS to allow 3D point clouds to be extracted. This should improve the quality of the segmentation results for near- and mid-range (i.e. rock detection) and for wide baseline MastCam far-range results. They will be integrated into the sourceforge Open Source StereoViewer Java-based workstation [3] In future, additional 3D measurement tools will be developed within the EU-FP7 PRoViDE2 project, which started on 1.1.13.

Acknowledgements: The authors would like to thank the UK Space Agency in general and A. Kuh and S. Horne in particular for their support of this work.

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