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New geological products from MSL using machine vision

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Abstract

Sedimentary layers and rocks strewn on the landscape are important geological markers to study the effects of water, wind, heat, impact and volcanic activities on a planetary surface. In order to aid field geologists to find and analyse such features, we have developed a set of computer vision tools to be able to identify and digitise sedimentary layer boundaries and rocks from MSL MastCam together with 3D information derived from NavCam stereo imagery.

1. Introduction

The NASA MSL Curiosity 100mm focal length MastCam cameras provides [1] a new capability to obtain images with a scale of 7.4 centimetres per pixel at a 1 km distance, and around 150 microns per pixel at 2 metres' distance. These represent a factor of 3.67 times higher spatial resolution than the Mars Exploration Rover (MER) PanCam. MastCam enables very detailed 360-degree panoramic mosaics to be produced (e.g. The Curiosity Bradbury Landing Mosaic) as well as zoom shots of particular features of interest identified in NavCam images. With the help of computer vision algorithms, we therefore have an opportunity to analyse, identify, and recognize complex geologies on Mars.

In this paper, we demonstrate using MSL 100mm focal length MastCam PIO (NASA Public Information Office) images and NavCam PDS stereo imaging data, how we can automatically detect and distinguish geological features.

2. Methods

In layer detection, we start the process with morphological and Gaussian smoothing to enhance the high intensity gradient and connect them into edges [2]. Then we apply a combined Sobel edge detection and morphological gradient detection detected lines are then binarised, filtered by connected component checking, and skeletonised for analysis of their direction and length.

In rock detection, we start with a morphological closure operation followed by bilateral filtering to the original image as pre-processing to smooth off the sandy surface whilst sharpening the edges. Then we apply the mean-shift [3] algorithm based on the Lab colour space of the pre-processed image to classify and label potential rocks. The mean-shift results are applied back to the original image and labelled as foreground pixels in Graph Cuts (GC) [4] segmentation. We also perform Canny edge detection and Adaptive thresholding on the pre-processed image and label the detected edge pixels as preliminary foreground pixels on the original image as initialization of GC. The final step is the application of GCs to iteratively define the foreground (rock) pixels and background pixels based on an initial guess from previous steps.

For MSL NavCam images, we extended the rock detection process by segmentation of the 3D range images, performing a range check on the detected rocks based on the stereo calibration information extracted from the PDS headers. This improved the quality of the segmentation results for near- and mid-range detection.

3. Experimental results

Figure [1] shown here is a portion of a larger image taken by Curiosity's 100-mm focal length Mast Camera on Sol 17 (0017MR0050002000I1_DXXX), showing the base of Mount Sharp, the rover's eventual science destination. The detected layer boundaries are labelled with a red colour.

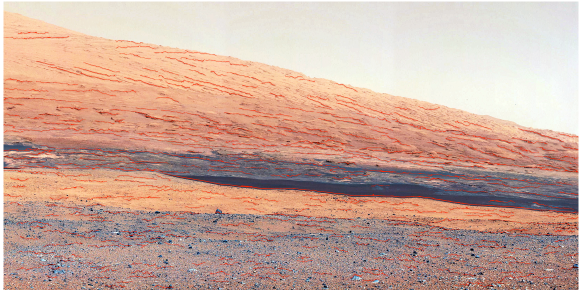

Figure 1: Detected linear layers labelled in red for a subset of MSL MastCam PIO Image on Sol 17

Figure 2 shows the rock detection result based on the Mean-shift/GC segmentation and 3D range discrimination, using MSL NavCam PDS left/right images on Sol 49 (NLA_401848313EDR_F0042778NCAM00409M1/ NRA_401848313EDR_F0042778NCAM00409M1).

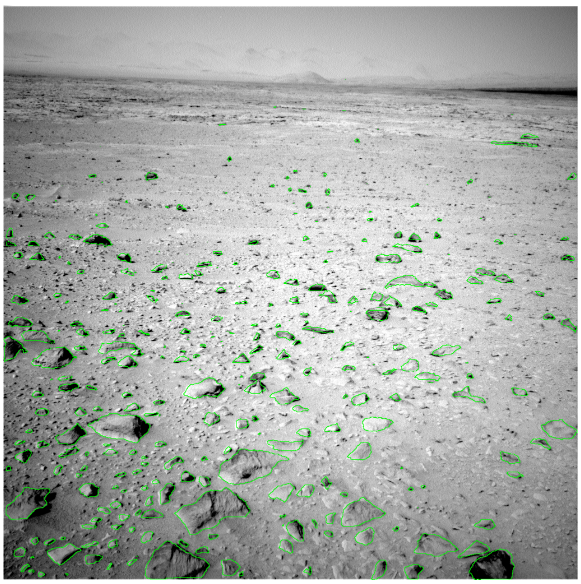

Figure 2: Detected rocks labelled in green for MSL NavCam PDS Image on Sol 49

6. Software specification (LRD-STK)

The Layer and Rock Detection toolkit (LRD-STK) is written in C++. It was initially developed for PIO pictures from the MSL MastCam at Mullard Space Science Laboratory (MSSL) at University College London (UCL). It uses the cross-platform QtSDK for easy installation on any different target operating system. It has also been integrated into PRoViP, which is the core-processing engine in the EU-PRoVisG project for MER image processing (http://provisg.eu). These tools are being integrated into the sourceforge Open Source StereoViewer Java-based workstation [5]. In future, additional 3D measurement tools will be developed within the EU-FP7 PRoViDE [6] project (http://provide-space.eu), which started on 1.1.13.

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