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A Multi-resolution 3D Reconstruction Tool: Exemplar using MSL NavCam PDS and MastCam PIO imagery

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Abstract

The acquisition of multi-resolution ground level imaging data from different cameras onboard the NASA MSL Curiosity, such as the Hazcams, Navcams, Mastcam and MAHLI, enable us to study a particular area/objects at various levels of detail. However, to analyze the structural differences properly or to do any extensive classification and recognition requires 3D information as well as the 2D data from all of these cameras. This requires 3D reconstruction and co-registration of stereo rover and non-stereo rover imagery.

In this paper, we describe the operation of a stereo reconstruction tool (StRec) with examples on 3D ground reconstruction from both stereo and non-stereo cameras using MSL data to obtain a multi-resolution 3D product.

1. Introduction

During the work on EU-PRoVisG project (http://provisg.eu), MSSL successfully developed systems for stereo visualisation [1], reconstruction [2] and analysis of various planetary robotic missions based on stereo rover data. However, the close-range reconstruction work shown to date has been constrained by the resolution of the fixed baseline of the stereo cameras on the rover (called here intra-stereo). Scientific analysis of complex geologies on Mars, such as the sedimentary layers and rocks that we demonstrated in [3] require high quality 3D mesh data and precise geographic information. Given the capability of MSL MastCam-34 with a pixel scale of 450 μm at a 2 m range and MastCam-100 with ~150 μm which provide three times higher resolution than the PanCams on Mars Exploration Rover (MER), a co-registered MastCam DTM can be generated for studying a local environment with precise geo-information and the best ever resolution.

Based on the development work done during the PRoVisG project, we have extended our wide baseline stereo reconstruction tool to be able to produce multi-resolution 3D products via co-registration of images from different cameras. In this paper, we demonstrate this data fusion capability using the publicly released NavCam stereo PDS data to provide 3D terrain context and co-registered MastCam images from the NASA Public Information Office (PIO) website in order to reconstruct a high-resolution 3D colour model.

2. Methods

We initially use the CAHVOR camera model stored in the PDS header for intra-stereo reconstruction and inter-stereo network building. For intra-stereo reconstruction, a SIFT/SURF feature based matching algorithm [5][6] is used to obtain a list of sparse Tie-points (TPs), a Cooperative Shape Adaption (CSA) optionally being used for TP optimization. Then we use these TPs to rectify the left and right images into epipolar geometry. In the densification/stereo-matching step, a region growing/ALSC based approach [2] or Semi-Global Matching (SGM) [4] can be used to produce dense disparity maps. After triangulation of each intra-stereo pair, Bundle Adjustment (BA) is used to correct the inter-stereo reconstruction and update the extrinsic calibration data. The MastCam data is co-registered to NavCam data via a SURF/CSA based approach before intra-stereo reconstruction. This process is further optimized with CAHVOR data once the original MastCam PDS data released. A schematic of the overall process is shown in Figure 1.The end result is a set of 3D point clouds which are in a common georeferenced framework along with very high resolution 3D point clouds wherever MastCam34/100 can be employed to generate much denser and finer 3D points and image texture. In this way we have the ability to make 3D measurements of science targets.

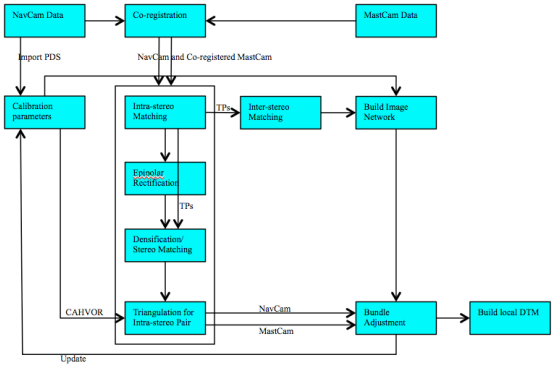

Figure 1: An example of a MastCam and NavCam DTM reconstruction processing chain implemented in StRec.

3. Experimental Results

An example 3D Model is shown in Figure 2 from 5 pairs of NavCam images on Sol 48 when Curiosity observed the so-called "Jake's rock". With such an unusual shaped rock, a multi-resolution 3D information is essential for deeper analysis.

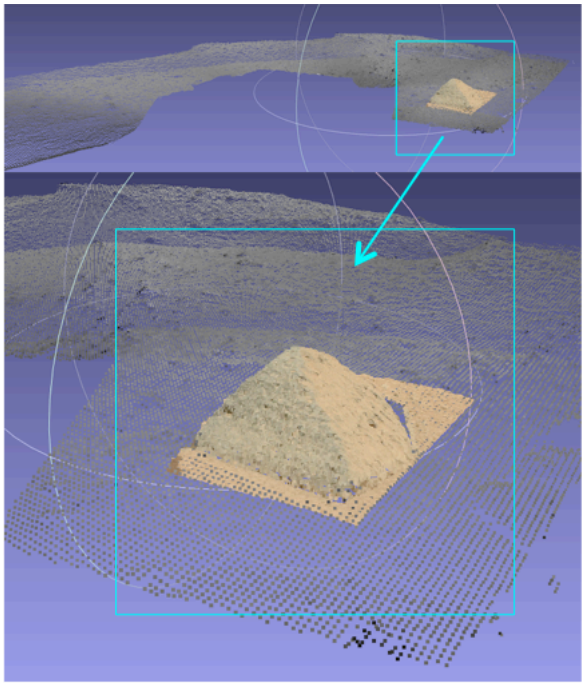

Figure 2 An example of reconstructed multi-resolution 3D model using MSL NavCam (1cm) and MastCam (0.1cm) images on Sol 48

5. Software Specification

StRec [2] is a C/C++ software tool initially developed for MER stereo image processing in the PRoVisG project at MSSL at University College London (UCL). It uses the cross-platform QtSDK for easy installation on a different target system. The basic functions of the software include a) image feature detection and matching b) epipolar rectification c) stereo 3D reconstruction. However, an experienced user can use this tool to build a more complex processing workflow by re-organizing the implemented processing steps in a specific way. This tool has been extended to 3D data processing, co-registration, and multi-resolution reconstruction within the PRoViDE project (http://provide-space.eu), which started on 1.1.2013.

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