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Dense Intra-stereo Matching for Mars Exploration Rover Data Fusion

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Abstract

Dense image matching is one of the core processing steps for MER data fusion, in order to produce a local DTM and the associated ortho-rectified image from multiple MER stereo pairs. Inspired by previous research employing two customised matching algorithms for inter and intra-stereo images, this paper presents a dense intra-stereo matching pipeline which does not require additional data interpolation after the intra-stereo matching. The proposed MER data fusion workflow is being re-used to configure an Orbital-and-Rover data fusion workflow within the EU-FP7 ProVisG poject.

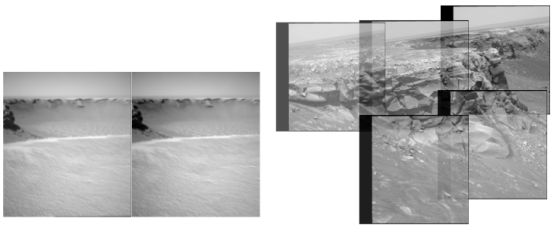
1. Introduction

The NASA Mars Exploration Rover (MER) is equipped with different stereo sensors, amongst which the Panoramic Camera (PanCam) and Navigation camera (NavCam) imagery are heavily used for rover navigation and scientific scene analysis [1]. Aside from these basic applications, recently close (<5m) and mid-range (<10m) stereo pairs are extensively exploited in an image-based rover localisation technique, referred to as visual odometry [2].

In order to take advantage of the high-resolution ground level images more efficiently, it is necessary to combine multiple images from different rover positions in a global context. For example, previous work [3,4] established an image network from the image matching to produce a local DTM.

In this approach, multiple images are classified into one of two groups, such as the intra-stereo pair having a large overlap between images [see Fig. 1(a)] and the inter-stereo pair from a wide baseline stereo pair (e.g., adjacent images from a panning motion) [see Fig. 1(b)]. From each intra-stereo pair, 3D data can be reconstructed and subsequently back-projected to inter stereo pairs in order to estimate tie points. However, the intra matching algorithm used in previous methods is not dense enough, so that the initial 3D data needs to be interpolated to connect inter-stereo images.

To avoid this data interpolation, the proposed MER data fusion workflows adopts a dense stereo matching algorithm, which uses a modified GOTCHA algorithm with an initial matching result from scale invariant interesting points.



(a) (b)

Figure 1 Example of intra (a) and inter-stereo pair (b): (a) NavCam stereo pair from MER-B at Victoria crater and (b) Five PanCam pairs around Cape desire.

2. Proposed matching workflow and preliminary test result

The proposed intra-stereo matching workflow consists of three major processing blocks: Affine and Scale invariant tiepoint selection, Densification, and Triangulation and Sparse Bundle Adjustment (SBA) [see Fig. 2]. The first processing block has been designed to choose the type of scale invariant Interesting Points (IP) between Difference of Gaussian (DoG) and Determinant of Hessian matrix [5]. Once IP's are ready, the chi-squared distance-based descriptor matching defines initial scale

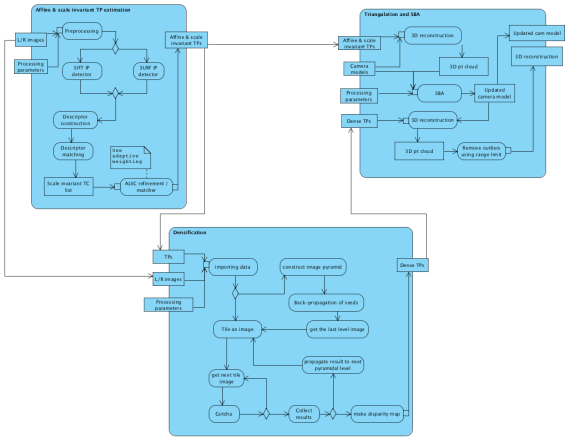
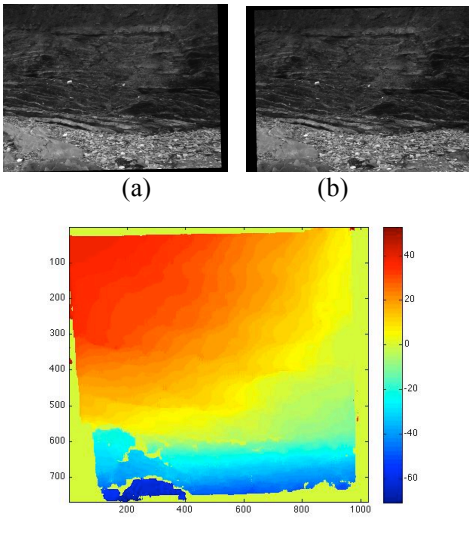


Figure 2 Block diagram of the proposed inter-stereo matching workflow

invariant tiepoints (TP's). The final TP's are obtained by ALSC feature refinement to account for the affine distortion between images and remove potential outliers from the initial TP's [6].

The TP result is subsequently fed to both remaining processing blocks. In Densification, it is used as seed points for the stereo region-growing algorithm, whilst it is used for updating camera exterior parameters in the SBA build block.



(a) (b)

(c)

Figure 3 Example of the stereo matching result with the proposed method: (a)-(b) left and right image from the ExoMars PanCam test campaign in Clarach bay; (c) horizontal disparity map

Figure 3 shows an example of the matching result. The left and right images shown in Fig. 3 (a) and (b) are captured from the ExoMars PanCam test campaign in Clarach bay and initially processed by Joanneum research Institution for epipolar alignment. Using this stereo pair, the proposed method produces 482,932 matches from the1024x768 image pair.

3. Conclusions and future work

In this research, we have successfully demonstrated a dense intra-stereo matching algorithm. The proposed method will be integrated into the MER data fusion and Orbital-and-MER data fusion, which are being developed at UCL under EU-FP7 ProVisG project.

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