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Super-resolution of repeat-pass orbital imagery at 400km altitude to obtain rover-scale imagery at 5cm

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Abstract

This paper introduces the results of a new image processing technique to reconstruct super-resolution imagery from multiple overlapped orbital images.

1. Introduction

Since 2007, high-resolution imagery (≈25cm) from the NASA HiRISE instrument have been acquired for around 1.4% of the surface of Mars from orbit. This allows rover engineers to determine to high accuracy the location of rovers to tens of cm precision through the co-registration of common homologous features visible in onboard rover cameras, which can be matched to those visible in orbital images [1]. Recently, a super-resolution restoration technique has been developed [2]. This takes multiple overlapping HiRISE images as input to generate up to 5cm super resolution imagery depending on how many overlapping images are available.

We demonstrate results of the algorithm to reconstruct 5cm super-resolution image from a subset of repeat-pass HiRISE images covering the MER-A rover traverse area.

2. Method

Non-redundant information is contained in multiple repeat-pass orbital imagery, which can be exploited to generate a high-resolution image. We modelled the spacecraft imaging system with guestimates of the Point Spread Function (PSF) blurring effect, camera motion, sampling effects, and noise term and developed a new algorithm to reconstruct stochastically toward optimal reconstruction.

The current state of the art super-resolution techniques in computer vision assume a sub-pixel shift of motion prior for low-resolution image sequences. However, this is not the case in orbital datasets where pixel shifts can be huge due to camera viewing angle differences.

Our super-resolution processing chain takes roughly aligned overlapping low-resolution images as input to generate tiled motion vectors with respect to different levels of pixel shift compared with a reference frame. Then we use steepest descent to resolve the Total Variation (TV) prior of the Maximum a Posteriori (MAP) equation. The algorithm is a variation of TV [3], which has been widely used in image deblurring, based on Gotcha matching [4], which has been used in stereo reconstruction area at UCL for the last 25 years.

3. Results

Figure 1 shows a 5cm super-resolution image of the MER-A Homeplate area reconstructed from 8 overlapping 25cm HiRISE images. Figure 2 shows a set of zoomed-in views showing restorations of rocks, edges and rover tracks cf with 25cm HiRISE images.

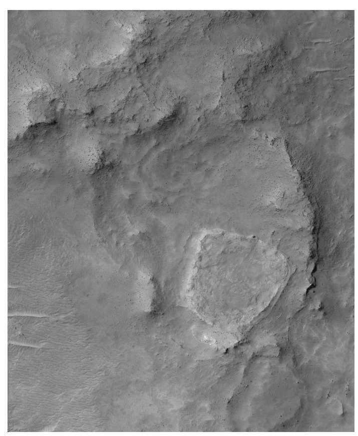

Figure 1 Super-resolution restoration image at 5cm for MER-A Homeplate.

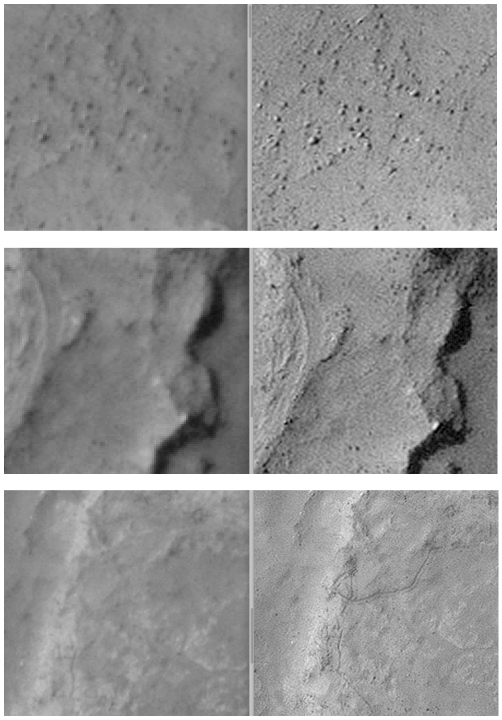

Figure 2 Zoomed-in views comparing oen of the input 25cm HiRISE image (left) and 5cm super-resolution image (right) within different part of MER-A Homeplate area.

4. Summary and Conclusions

This paper has shown initial results of the super-resolution technique, which has been developed within the EU-FP7 PRoViDE project (http://provide-space.eu) [5]. We briefly introduced the Gotcha-TV algorithm developed specifically for super-resolution restoration of orbital dataset. The outcome result is important to rover localisation [6], path planning, and landing site selection for on-going and future rover missions. The super resolution results for MER-A has been applied to our ground-to-orbit fusion work [1] and been imported into an interactive web-GIS system, PRoGIS (http://progisweb.eu), which was originally developed within the EU-FP7 PRoVisG (http://provisg.eu) and PRoViDE project to enable geologists to perform close-up visual analysis of key features at different resolutions from HRSC, CTX, HiRISE to super-resolution HiRISE and rover imagery.

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