ANALYSIS OF MARS ORBITER CAMERA STEREO PAIRS

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Introduction

The Mars Orbiter Camera (MOC) has been operating on board of the Mars Global Surveyor (MGS) spacecraft since 1998. It consists of three separate cameras - Red and Blue wide angle cameras (FOV=140 deg.) and Narrow Angle camera (FOV=0.44 deg.). The Wide angle camera allows surface resolution on the order of 230-500m/pixel and the narrow angle camera - 1-5m/pixel. We have attempted to extract topography information, employing the latest MOC camera model. We present results from Red Wide angle camera and Narrow Angle camera.

Method

The basis for stereo image processing described in this work are the image correlation tools developed as a part of the VICAR (Video Image Communication And Retrieval) software suite at the Multimission Image Processing Laboratory (MIPL) at JPL. VICAR has been developed since 1966 to digitally process multi-dimensional imaging data.

We employed VICAR tools used for geometric rectification (GEOMV) and automatic tiepoint matching (program TRACKER3) with a properly calibrated camera model (SPICE I-kernel, [2]) for MOC Wide and Narrow angle cameras instrument. The basis for robust recovery of tiepoints from two images is the Gruen correlation algorithm, which has been implemented in VICAR [4]. This approach was successfully used to produce topography maps for the Mars Pathfinder [3], track features in Jupiter cloud decks ([6, 5]). VICAR programs and scripts developed for this task may be easily adopted for use with the THEMIS visual and Viking images.

VICAR uses Gruen image correlation [1], which permits limited image rotation and skew. The initial tiepoint locations are predicted by the camera model and later refined by the means of Gruen image correlation. The correlator has three hierarchical modes: (1) A classical spatial least squares correlation on integral pixel boundaries used when rotation is small; (2) An annealing non-deterministic search used when rotations are unknown; (3) A simplex deterministic search used for the end game. The correlations are performed autonomously without interference from an operator. Gruen's scheme is in essence a 2-D correlation and it does not require images to be aligned in the line direction. The Gruen's scheme performs very well, when camera information is known with significant errors.

TRACKER3 routine provides the most useful interface for the feature tracking and automatic tiepoint identification for stereo processing. This program takes two images as input and automatically finds all tiepoints in the images with accuracy down to about 0.1 of a pixel. The tiepoints can be used for either referencing target image to the reference image, or for detecting change between time separated image sequence.

Recovery of topography information from stereo pairs followed standard processing scheme :

1. Perform radiometric calibration of the images (using ISIS tools for MOC processing)
2. Perform rectification of the images (project into the same reference frame) using the best known camera model. Pointing knowledge is very important at this step.
3. Use TRACKER3 routine for to automatically obtain tiepoints from both images.
4. Use XOVER subroutine for all tiepoints to obtain location of intersecting rays projected from a camera.

Results of this processing are discussed in the next section.

Results

We have carried out stereo analysis on both Wide Angle (Fig. 1) and Narrow Angle MOC stereo pairs (Fig. 2).

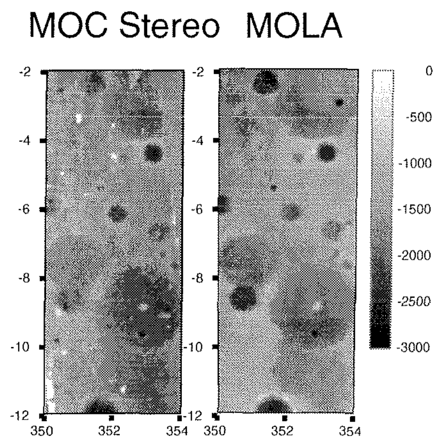

Figure 1: Comparison of topography retrieved from automated MOC stereo pair analysis (left panel) with MOLA topography (right panel) for the same region. MOC Wide-Angle Images M01-00457 and M01-03724 were used. Gray area in the MOC picture is where MOC data was absent. Resolution of both maps is the same -2km/pixel. MOC stereo allows resolution down to about 1km/pixel and does not have "missing crosstracks" problem.

MOC Wide-Angle stereo pairs. We have used Wide-Angle images taken during the Geodesy campaign. During this campaign all available (due to orbit characteristics) Martian surface was mapped by the Wide-Angle camera at about 300 to 500 m/pixel in both nadir and off-nadir orientations. Data taken during this period of time enable analysis of almost all of the Martian surface in stereo. Images were processed according to the scheme described in the previous section. In order to check our algorithm, we have compared retrieved topography with the finest scale MOLA topography. We have found very good agreement (see Fig. 1) between topography recovered from stereo and precise MOLA altimetry. In general, horizontal resolution of stereo pairs is on the order of 500m/pixel. Resolution of recovered topography is about 2 km/pixel, which is comparable with the MOLA 1/32 degree product. Topography, recovered from MOC stereo pairs, produces good results relative to MOLA, but considerably noisier than MOLA topography. Wide angle stereo pairs can be used where MOLA can not achieve good coverage due to orbital constraints - equatorial regions, polar regions poleward of 87.1 deg. A side product from the Wide Angle image rectification is a global 300 m/pixel mosaic of the Martian surface.

MOC Narrow-angle stereo pairs. Over the course of Mapping and Extended missions MOC camera has been targeted to take stereo images of selected landing sites. Landing site targets included Viking Landers, Mars Polar Lander, Pathfinder and future candidate sites for Mars Exploration Rovers (MER). The best stereo pairs were obtained during the Extended mission, when taking data for the MER landing site selection process.

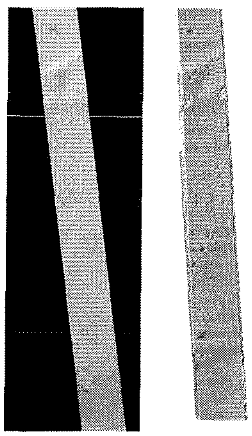

Figure 2: Actual image (E02-00665, left panel) and corresponding shaded relief map from Narrow Angle stereo pair (E02-00665 and E03-01453, right panel). Note small undulations in the recovered topography due to fine scale oscillations of the spacecraft.

Here we present results from analysis of narrow angle images E02-00665 and E03-01453. This stereo pair is of very high quality and illustrates common problems that we have encountered. We have collected almost 1 million tiepoints. Fig. 2 shows the actual image E02-00665 and shaded relief map, constructed from the stereo topography. All topographic features can be clearly identified in shaded relief map. However, there are some small scale undulations in the image, which are believed to be due to very small scale oscillations of the spacecraft. The cause of these oscillations is unknown. These results are consistent with analysis of the same stereo pair performed by Kirk et. al (2001, personal communication). They have analyzed more data from the extended missions and observed the same effects in other stereo pairs.

Summary

We have demonstrated new stereo image processing capabilities developed for the VICAR image processing system. Topography obtained from analysis of stereo pairs is consistent with the MOLA topography (MOC Wide-Angle images). Meter and decimeter scale topography can be derived from Narrow Angle stereo pairs.Detailed analysis of the Narrow Angle images revealed previously unknown oscillations of the spacecraft. Narrow Angle processing results are consistent with the results obtained by Kirk et. al.

We hope to perform analysis of more stereo pairs from MOC and ultimately bring Viking and Mars Odyssey's THEMIS visual subsystem images into our processing. Data resulting from the stereo pair analysis will be of high value for investigations of meter-scale topographic structures on Mars and future landing sites selection process.

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References

[1] GRUEN, A., AND BALTSAVIAS, E. Adaptive least squares correlation with geometrical constraints. In SPIE Computer Vision for Robots (Cannes, 1985), vol. 595.

[2] KIRK, R. L., ET AL. Geometric Calibration of the Mars Orbiter Cameras and Coalignment with the Mars Orbiter Laser Altimeter. In Lunar and Planetary Institute Conference (Mar. 2001), vol. 32, pp. 1863+.

[3] LAVOIE, S. K., ET AL. Processing and analysis of Mars Pathfinder science data at the Jet Propulsion Laboratory's Science Data Processing Systems Section. J. Geoph. Res 104 (Apr. 1999), 8831--8852.

[4] LORRE, J. J. Function minimization with partially correct data via simulated annealing. In Applications of Digital Image Processing (1988), vol. 595, SPIE, pp. 398--403.

[5] LORRE, J. J., AND HANDLEY, T. H. Registration assisted mosaic generation. Tech. rep., JPL, 1999. TMOD Quartery Report.

[6] VASAVADA, A. R., ET AL. Galileo imaging of jupiter's atmosphere: The great red spot, equatorial region, and white ovals. Icarus, 135, 1 (1998), 265--275.