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Models of Mars based on the ESA Mars Express and NASA Mars Reconnaissance Orbiter data

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Abstract

We describe a processing system for generating multi-resolution digital terrain models (DTM) of Mars within the the iMars project of the European Seventh Framework Programme. This system is based on a non-rigorous sensor model for processing high-resolution stereoscopic images obtained from the High Resolution Imaging Science Experiment (HiRISE) camera and Context Camera (CTX) onboard the NASA Mars Reconnaissance Orbiter (MRO) spacecraft. The system includes geodetic control based on the polynomial fit of the input CTX images with respect to to a reference image obtained from the ESA Mars Express High Resolution Stereo Camera (HRSC). The input image processing is based on the Integrated Software for Images and Spectrometers (ISIS) and the NASA Ames stereo pipeline. The accuracy of the produced CTX DTM is improved by aligning it with the reference HRSC DTM and the altimetry data from the Mars Orbiter Laser Altimeter (MOLA) onboard the Mars Global Surveyor (MGS) spacecraft. The higher-resolution HiRISE imagery data are processed in the the same way, except that the reference images and DTMs are taken from the CTX results obtained during the first processing stage. A quality assessment of image photogrammetric registration is demonstrated by using data generated by the NASA Ames stereo pipeline and the BAE Socet system. Such DTMs will be produced for all available stereo-pairs and be displayed as WMS layers within the iMars Web GIS.

1. Introduction

Understanding the role of different planetary surface formation processes within our Solar System is one of the fundamental goals of planetary science research. There has been a revolution in planetary surface observations over the last 15 years, especially in 3D imaging of surface shape. This has led to the ability to be able to overlay different epochs back to the mid-1970s, examine time-varying changes (such as the recent discovery of boulder movement, tracking inter-year seasonal changes and looking for occurrences of fresh craters.

To track changes on the planet Mars it is important to compare data from different sensors and therefore address issues of varying image resolution, lighting conditions and coverage and co-registration. The goal of this work is to generate digital terrain models using the data from different Mars orbiters and use these models for making different resolution imagery data consistent with each other to improve the performance of the tools for detecting planetary surface changes.

The algorithms developed by Kim & Muller [1], [2] were further updated by employing an advanced image matcher in matching iterative window selection and improved sensor model strategy.

2 Processing chain

The initial image-processing uses the camera models for two instruments onboard the Mars Reconnaissance Orbiter (MRO CTX): the Context Camera (CTX) instrument obtains grayscale images of the Martian surface with a spatial resolution of about 6 meters per pixel over a swath that is about 30 kilometers wide. The instrument consists of a 350 mm focal length, 6 degree field of view, catadioptric Maksutov-Cassegrain telescope that images onto a 5064 pixels-wide charge coupled device (CDD) line array. The CCD detects a broad band of visible light from 500 to 800 nanometers in wavelength. The instrument includes a 256 MB DRAM buffer, so that it can acquire pictures that have downtrack lengths greater than 160 kilometers (99 miles). In other words, a typical CTX image can be as wide as 30 km and as long as 160 km.

The HiRISE camera (McEwen et al. 2007) is a detectors capable of generating images of up to 20,264 cross-scan observation pixels (exclusive of overlap pixels) and 65,000 unbinned scan lines

The processing chain co-registers the CTX images to the HRSC reference image and then the HiRISE images to the CTX image by using a feature-detection algorythm and applying a polynomial fit of the target image to the reference image.

The adaptive least-squares correlation method applied here was updated by Otto & Chau [4] using a region growing approach. The basis of this algorithm was to start with an approximate match between a single point in the left image and a point in the right (corresponding stereo pair) image. This starting point is known as a “seed-point” [5].

After stereo matching and obtaining a disparity map, a XYZ-point cloud is generated and adjusted to the DTM of reference (HRSC) by using the NASA Ames stereo pipeline tools.

3 Product quality assessment

The quality assessment of the obtained results were made by comparing the output DTMs with those produced by the NASA Ames stereo pipeline (ASP) and the BAE Socet System (SS) applyed to the same regions on Mars. For this purpose we have chosen input CTX and HiRISE images of the three most observed sites on Mars: Mars Science Laboratory (MSL Curiosity); Mars Exploration Rover A (MER-A Spirit) and Mars Exploration Rover B (MER-B Opportunity). The supporting (reference) DTMs and images were taken from the HRSC products operlapping with the CTX images.

The averaged difference between the averane HRSC, ASP and SS DTMs and our results for CTX was $+1.4 \pm 84.2$ m, -2.1 ± 84.4 m and -2.7 ± 84.9 m, respectively. The same differences for the HiRISE instrumen were -13.3 ± 19.7 m, $+4.2 \pm 19.7$ m and $+2.3 \pm 37.2$ m. The large dispersion of the differences is due to the larger number of surface features over the larger area for CTX and smaller numer of features for smaller area covered by the HiRISE instrument. The results have been considered as satisfacttory which allows using our processing for generating multi-resolution DTMs and ortho-rectified images for their further use in the surface change detection processing chain.

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