XXI Congress

ernational Society for Photogrammetry and Remote Sensing
3-11 July 2008, Beijing China

ABSTRACT SUBMISSION FORM

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Title of the Paper	Automated Noise Reduction in HRSC Mars DTMs
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Technical Session [3]	Extraterrestrial Mapping
Keywords (5-8) [4]	Extra-terrestrial, Mapping, DTM, Surface, Matching, Geology

ABSTRACT(800-1000 words) [5],[6]

A key fundamental scientific question in the exploration of other planets is whether conditions favourable to the development and presence of life exist or have existed in the past. Central to this issue is the search for evidence of past (and present) water, including the determination of how much water was present at or near the surface. Of all the planets in the Solar System, Mars is the nearest and perhaps the best candidate for addressing these questions, and hence has been the main focus of significant planetary exploration to date. Determining the inventory of water reservoirs and outflow channels on Mars provides critical information for understanding the geological, climatic and potentially astro-biological evolution of the planet.

Previous studies of the role of water on Mars have been severely hampered by the spatial resolution of topographic data available to study Martian landforms. Whilst extensive but low resolution Viking imagery, and high resolution, but spatially restricted, imagery taken from Mars Observer Camera-Narrow Angle (MOC-NA) and Thermal Emission Imaging System (THEMIS) have been available, the lack of high resolution topographic data with which to investigate meso-scale (1-100 km scale) landforms in detail has restricted the analysis and interpretation of Martian surface features. A detailed investigation of landscape formation and evolution requires high resolution and accurate topographic data from which fine-scale clues to the origin of landforms can be resolved and quantitative measurements of landscape properties determined.

Since the European Space Agency (ESA) Mars Express spacecraft entered an elliptical orbit around Mars on the 25th of December 2003, the High Resolution Stereo Camera (HRSC) placed onboard has been imaging the Martian surface. Due to HRSC's characteristics of high resolution and stereo imaging capability, the construction of Digital Terrain Model (DTM) of Mars surface topography with a grid spacing of 30-50 metres is feasible for most areas. By visualising the Martian terrain in a high resolution three-dimensional model, the evolution of the Martian surface and the geological processes involved can be effectively and correctly analysed.

In order to select and certify an area for future exploration, DTM data quality is a very important aspect of the geological investigation of Martian surface. Errors/blunders (outliers) and false features occurring in any DTM will lead to an incorrect interpretation and understanding of surface processes. This paper therefore aims to determine and remove such noise existing in any Martian terrain model produced from HRSC stereo imagery. Moreover, the errors appearing in the final DTM product, rather than the ones in the intermediate steps in the process of DTM generation, are dealt with in this paper, i.e. this is an "a posteriori" method.

Surface matching is a technique used to carry out co-registration of point clouds and has been applied broadly in the fields of computer vision and geomatics. Its applications can be characterised as (i) registration of objects or surfaces comprised of 2½-dimensional or three-dimensional point feature data, (ii) detection of differences between objects or surfaces, and (iii) integration of datasets generated from different sources (Mitchell and Chadwick, 1999). By far the most common algorithms used in surface matching have been based on some form of least squares adjustment, minimising the differences in position between the surfaces. Once the matching is finished one of the by-products is the ability to detect differences, as the residuals from the least squares calculation are the surface separations. Examination of these may reveal actual differences that may have occurred between the surfaces produced by different techniques (Pilgrim, 1996). Based on this approach, a surface matching technique is proposed here to perform

noise reduction in Mars DTM.

Preliminary testing has followed a two-stage process. In the first step, two point clouds are matched, one from 3D intersection points derived from HRSC stereo images and a second point set from the corresponding area measured by the Mars Orbiter Laser Altimeter (MOLA). The former dataset was constructed using the DLR modification of the JPL Video Image Communication and Retrieval (VICAR) software with the matcher developed at UCL (Kim and Muller, 2007) whilst the latter point cloud comes from the global Mars DTM at around 500m spacing. HRSC has a height accuracy of around 15-20m but with point spacing at 30-50m whilst MOLA footprints were acquired every 300m with a 170m footprint with a height accuracy of around 2 m locally and 30 m globally (Smith et al., 2001). MOLA is deemed as the "true" terrain model of Mars and is thus input as the reference surface during the matching. Once the matching is finished, the HRSC point model is transformed and the residuals which represent the disparities between the two point clouds are obtained. The points with residuals over a given tolerance value are flagged as noise and removed from the HRSC point cloud. The second part of the experiment is to create a high resolution DTM from the set of remaining points. Due to the advantages of fast processing speed, easy manipulation and the direct use of each data point (McCullagh, 1998), a Triangular Irregular Network (TIN) is applied to represent the DTM structure. In order to improve the resolution of the DTM, interpolation is carried out in each triangle to obtain a greater level of detail. Subsequently, surface matching is performed again to match the updated point cloud with the MOLA data and the noise points generated from the interpolation are removed. The process is iterated until the required resolution of the DTM is met.

The solution for automated noise reduction proposed in the paper is expected to be an efficient method for refining Mars DTMs produced from HRSC stereo imagery, which is of great value for improving hydrological analysis and geological investigations of Martian surface. The details of the method, as well as the results of all the experiments, some discussion and further works will be described in the full paper.

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