Discrete and continuous image matching methods applied to DTM generation with Hirise images

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NASA's Mars Reconnaissance Orbiter blasted off from Cape Canaveral in 2005, with the primary scientific objective to perform remote sensing investigations to characterize the surface, subsurface and atmosphere of the planet and identify potential landing sites for future missions (NASA/JPL). HiRISE, the linear pushbroom image sensor onboard MRO, provides images with up to 0.3 m ground resolution. Stereo image pairs are acquired over the highest-priority locations with an high accuracy. These data represent an enormous potential for the automatic generation of Digital Terrain Models (DTMs) thanks to the high level of details, the stereo capability and the colour images. Image matching is a surface reconstruction technique well researched and documented in the literature. It is agreed that with good texture and with an adequate image acquisition geometry very good results can be obtained by totally automated approaches: the matching completeness in such areas reaches high percentages and the image measurement accuracy is well below one pixel. Some stereo-images, together with navigation and calibration data have been downloaded from NASA's Planetary Data System (PDS). In our experimentation, images and orientation parameters were given as input to two different software based on different area-based image matching algorithms. The first performs image matching using a discrete (local) method (i.e. every homologous point location is estimated regardless of the results obtained in the neighborhood) while the second one implements a continuous (global) method (i.e. exploits global constraints that correlate the results obtained in neighboring points). Dense Matcher, a DTM reconstruction software developed at the University of Parma, is based on a classical Least Squares Matching approach and Dense Matching techniques. SIEM (Stereo-Images Evolving Models), developed by the University of Padova, uses snakes (described as “Evolving Models” in the acronym of the algorithm) as a tool to evolve an initial approximation of the stereo pair disparity map until an optimum global correspondence between the images is found. Under the external forces, represented by a similarity function, and the internal ones, represented by smoothness constraints on the disparity, the disparity map evolves as a deformable model from an initial approximation state until convergence. The paper reports on tests carried out to evaluate the performances of the two software packages and the metric accuracy of the DTMs generated through a series of comparisons. To test the algorithms under the same conditions and to make proper the comparison, we used the two different image matching strategies but the same triangulation method to compute ground coordinates. A number of DTMs have been generated with the two strategies to be compared with a 3D model as reference. To this aim, it was thought to use two different type of data: synthetic images and real images provided by HiRISE. For the production of the synthetic images we proceeded in this way: a virtual 3D model of geological features relevant to planetary science has been inserted in a virtual environment under 3D Studio Max. This software allows to define and place cameras in the scene, drape texture on objects, control illumination and generate synthetic images with different noise patterns for each camera. Using such images in the surface reconstruction process, the reconstruction error can be evaluated point wise as the distance of each point to the reference model surface which is known a priori. To validate the quality of our DTM obtained with HiRISE images and analyze the metric accuracy of the photogrammetric approach in the planetary contexts we perform a comparison with the MOLA DTM (Mars Orbiter Laser Altimeter). This DTM is the most consistent Mars DTM available to date. However, the geometric analysis suffers from the lack of a reference data set with superior accuracy, mainly because the MOLA DTM does not have an adequate planimetric resolution. To assess their impact on DTMs accuracy, DTM generation has been performed varying different input parameters in the data processing: different template sizes were used in order to evaluate the possible smoothing effect on the shape reconstruction. In order to try to improve the quality of the DTM generated, a Multi-Image strategy has been carried out. This approach is exclusive of the traditional Least-Squares Matching algorithm and for this reason has been tested just with Dense Matcher. The comparison between the DTMs has allowed to carry out an evaluation of metric accuracy of the local and global methods.