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EVALUATION OF AN AREA-BASED MATCHING ALGORITHM WITH ADVANCED SHAPE MODELS

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ABSTRACT:

The authors are part of a team in charge of the development of a STereo Camera (STC) for the ESA-JAXA mission BepiColombo to Mercury (Cremonese et al, 2009). STC will provide the images for the global mapping in stereo mode of the entire Hermean surface with a ground resolution varying from 50 m at the equator to about 115 m at the poles. In order to estimate and characterize the actual stereo reconstruction capabilities of STC, an indoor Stereo Validation Setup (SVS) has been developed and tested in laboratoy with a functional breadboard. The Simbiosys flight model has been recently integrated, the flight instrument calibration will be performed, and the stereo reconstruction capability will be checked. The stereo calibration will be performed by comparing the DTMs produced by the Dense Matcher software (DM), developed at University of Parma, measuring a series of rock samples stereo pairs with the ones produced by an high resolution laser scanning system. Among other preparation activities, algorithms and software for DTM generation from STC images have been developed. Originally developed for use in close range photogrammetry, DM has been optimized to cope with very high resolution images provided by the most recent missions (LROC NAC and HiRISE). Efforts have been mainly directed at the improvement of the image correlation kernel and of the process automation.
More specifically, important changes have been made to the correlation kernel, still maintaining its high performance in terms of precision and accuracy by implementing an advanced version of the Least Squares Matching (LSM) algorithm.
DTM generation with high level of accuracy and reliability is fundamental in order to faithfully reconstruct the terrain shape, particularly where there are strong discontinuities and changes in terrain slope. Commonly an affine transformation is used as geometric transformation in the area-based matching algorithms implemented in the Least Squares Optimization; however, perspective changes due to rough terrain morphology are difficult to accommodate by an area-based stereo correlator with such model only. An iterative algorithm has been devised to adapt the geometric transformation in image resampling using different shape functions. Many authors (Sutton & al., 1988) (Bruck & al., 1989) (Lu & Cary, 2000) (Hubert & al., 2002) found that the use of a simplified shape function requires less computational load but yields lower accuracy when significant changes in the terrain curvature occurs. Also Bethmann (Bethmann & al., 2010) showed that using different shape functions to model the geometric transformation in LSM can bring higher accuracy and solve, in some cases, numerical problems like pixel-locking. In this context, the new DM software uses, rather than the common affine transformation, alternative functional models in the geometrical transformation involved during LSM to handle perspective differences.
The aim of this paper is to evaluate the performances of such alternative geometric models in DTM reconstruction.Two models that will be considered: a projective transformation (8 parameters) and a polynomial function (12 parameters). The evaluation of the alternative models will be carried out in terms of accuracy and evaluating statistically the quality of the solution convergence. The test scenarios have been organized considering many processing variables and different set of images, in order to identify the difficulties in the matching phase. The tests have been executed on three sets of data: real images resampled with given transformation; synthetic computer-generated images; real images acquired by the STC flight model in the stereo validation setup and LROC NAC stereo pairs.
Results obtained with our matching software are compared with those of well established software such as Socet Set (Bae System) and Stereo Pipeline (NASA-Ames). The comparison of the performance of image matching being the main objective of this work, all other steps of the DTM generation procedure have been made independent of the matching software by using a common framework. Regarding real images, the comparison with the other planetary mapping software provides important information about the capability of the DM to reconstruct in 3D the surfaces of the planets by satellite images.
In order to evaluate the quality of a photogrammetric DTM, both external and internal quality indexes have been considered. The exterior quality (accuracy) should be computed through comparison with uncorrelated data that didn't participate in the generation of the DTM. (Karel & al., 2006). To this aim, as far as the procedures for the stereo validation and calibration of STC are concerned, reference laser data from a high accuracy laser scanner have been used to provide a high resolution 3D model of the rock samples.
A series of comparison has been performed by using LOLA altemeter data as reference for evaluate the LRO-NAC images process (at least for the evaluation of the vertical accuracy of the DTMs because the spatial resolution of the laser being very poor).

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Furthermore the evaluation of the stereo-DTMs will be performed in terms of output density (number of points per unit area), completeness of the surface description, level of details and morphological consistency. The matching accuracy for synthetic images will be evaluated in the image space and the assessment will be given both in internal and external terms: vertical accuracy will be evaluated by comparison with the laser acquisition and nominal values (for resampled images); the quality of the convergence to the solution will be statistically evaluated.