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Coregistration of high-resolution Mars orbital images

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The systematic orbital imaging of the Martian surface started 4 decades ago from NASA's Viking Orbiter 1 & 2 missions, which were launched in August 1975, and acquired orbital images of the planet between 1976 and 1980. The result of this reconnaissance was the first medium-resolution (i.e. $\leq$ 300m/pixel) global map of Mars, as well as a variety of high-resolution images (reaching up to 8m/pixel) of special regions of interest. Over the last two decades NASA has sent 3 more spacecraft with onboard instruments for high-resolution orbital imaging: Mars Global Surveyor (MGS) having onboard the Mars Orbital Camera – Narrow Angle (MOC-NA), Mars Odyssey having onboard the Thermal Emission Imaging System - Visual (THEMIS-VIS) and the Mars Reconnaissance Orbiter (MRO) having on board two distinct high-resolution cameras, Context Camera (CTX) and High-Resolution Imaging Science Experiment (HiRISE). Moreover, ESA has the multispectral High resolution Stereo Camera (HRSC) onboard ESA's Mars Express with resolution up to 12.5m since 2004. Overall, this set of cameras have acquired more than 400,000 high-resolution images, i.e. with resolution better than 100m and as fine as 25 cm/pixel.

Notwithstanding the high spatial resolution of the available NASA orbital products, their accuracy of areo-referencing is often very poor. As a matter of fact, due to pointing inconsistencies, usually form errors in roll attitude, the acquired products may actually image areas tens of kilometers far away from the point that they are supposed to be looking at. On the other hand, since 2004, the ESA Mars Express has been acquiring stereo images through the High Resolution Stereo Camera (HRSC), with resolution that is usually 12.5-25 metres per pixel. The achieved coverage is more than 64% for images with resolution finer than 20 m/pixel, while for $\sim$40% of Mars, Digital Terrain Models (DTMs) have been produced with are co-registered with MOLA [Gwinner et al., 2010]. The HRSC images and DTMs represent the best available 3D reference frame for Mars showing co-registration with MOLA<25m (loc.cit.).

In our work, the reference generated by HRSC terrain corrected orthorectified images is used as a common reference frame to co-register all available high-resolution orbital NASA products into a common 3D coordinate system, thus allowing the examination of the changes that happen on the surface of Mars over time (such as seasonal flows [McEwen et al., 2011] or new impact craters [Byrne, et al., 2009]). In order to accomplish such a tedious manual task, we have developed an automatic co-registration pipeline that produces orthorectified versions of the NASA images in realistic time (i.e. from $\sim$15 minutes to 10 hours per image depending on size).

In the first step of this pipeline, tie-points are extracted from the target NASA image and the reference HRSC image or image mosaic. Subsequently, the HRSC areo-reference information is used to transform the HRSC tie-points pixel coordinates into 3D "world" coordinates. This way, a correspondence between the pixel coordinates of the target NASA image and the 3D "world" coordinates is established for each tie-point. This set of correspondences is used to estimate a non-rigid, 3D to 2D transformation model, which transforms the target image into the HRSC reference coordinate system. Finally, correlation of the transformed target image and the HRSC image is employed to fine-tune the orthorectification results, thus generating results with sub-pixel accuracy. This method, which has been proven to be accurate, robust to resolution differences and reliable when dealing with partially degraded data and fast, will be presented, along with some example co-registration results that have been achieved by using it.

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