Generation of OSU HiRISE Orthophoto Based on MOLA-Controlled Bundle Adjustment Covering Spirit Rover Landing Site

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/* Identification Information */
DATA_SET_NAME             = "MRO MARS HIGH RESOLUTION IMAGING SCIENCE
                             EXPERIMENT ORTHOPHOTO"
PRODUCER_INSTITUTION_NAME = "THE OHIO STATE UNIVERSITY"
PRODUCER_ID               = "OSU"
PRODUCER_FULL_NAME        = "RON LI"
INSTRUMENT_HOST_NAME      = "MARS RECONNAISSANCE ORBITER"
INSTRUMENT_HOST_ID        = "MRO"
INSTRUMENT_NAME           = "HIGH RESOLUTION IMAGING SCIENCE
                             EXPERIMENT"
INSTRUMENT_ID             = "HIRISE"
TARGET_NAME               = "MARS"
SOURCE_PRODUCT_ID         = (PSP_001513_1655, PSP_001777_1650)
RATIONALE_DESC            = "Spirit Rover Localization"
SOFTWARE_NAME             = "OSU OrbiterMapper"
PURPOSE                   = "Spirit Rover Localization (Match with
                             traverse in PDS updated in June 2011)"

/* Parameters about Product */
COORDINATE_SYSTEM_NAME       = LANDING SITE LOCAL FRAME
LATITUDE OF ORIGIN           = -14.5692 <DEG>
LONGITUDE OF ORIGIN          = 175.4729 <DEG>
MAP_RESOLUTION               = 0.3 <M/PIX>
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/* Data Processing Procedure */

1. MOLA-controlled Bundle Adjustment

MOLA points are registered onto HiRISE stereo images by first registering the MOLA points onto Mars Orbiter Camera (MOC) stereo images, taking advantage of the fact that MOLA and MOC were on the same orbiter, the Mars Global Surveyor (MGS). Two MOC stereo images (E0300012 and R0200357) and one MOLA profile (ap19227l) were used in a MOLA-controlled bundle adjustment (BA). The MOLA profile was acquired simultaneously with the first MOC image (E0300012). Unfortunately, MOC image R0200357 does not have a simultaneously acquired MOLA profile due to a laser failure.

The first step was to integrate both MOC stereo images with the MOLA profile through a BA, in which the inconsistency between MOLA and MOC is reduced effectively.

Once the MOLA points are registered to the MOC images, in the second step MOLA points are transferred onto HiRISE stereo images by manually comparing the image features of their surrounding terrain features. Nine MOLA points were transferred and used to serve as ground control points for adjustment of the HiRISE exterior orientation (EO) parameters through a bundle adjustment of HiRISE with MOLA points.

In the BA, the image coordinates of each MOLA point on the HiRISE images are used to link the image space with the object space through a collinearity equation. A conceptual flowchart of the MOLA - controlled HiRISE BA procedure is shown in Figure 1.

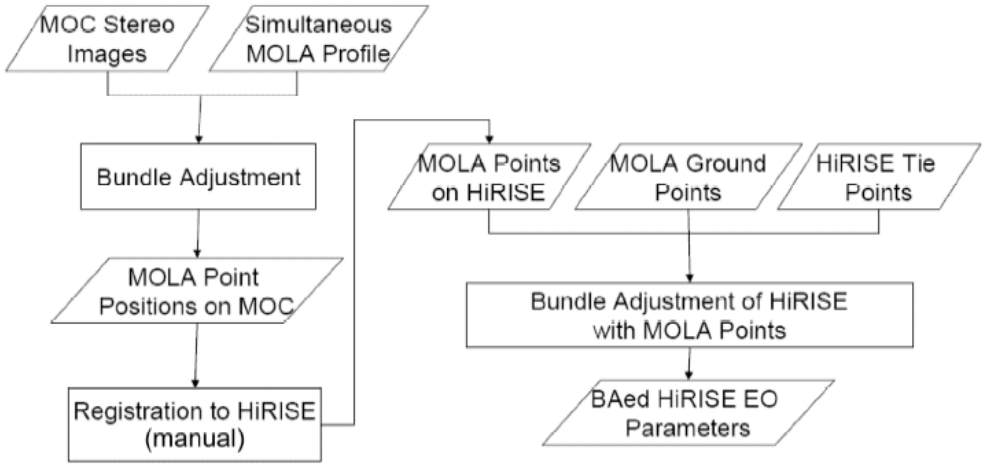


Figure 1. Conceptual flowchart of MOLA-controlled HiRISE BA procedure.

2. Coordinate Transformation

After BA, the HiRISE stereo images can be used to generate a DEM with refined EO parameters. However, the derived DEM is in the Mars Body Fixed (MBF) coordinate system and needs to be transformed to the Landing Site Local frame (LSL) for rover localization. The HiRISE DEM is transformed from the Mars Body Fixed (MBF) coordinate system into LSL using Equation 1

$$\begin{bmatrix} X_R \\ Y_R \\ Z_R \end{bmatrix} = \begin{bmatrix} -\sin\phi\cos\lambda & -\sin\lambda & \cos\phi\cos\lambda \\ -\sin\phi\sin\lambda & \cos\lambda & \cos\phi\sin\lambda \\ \cos\phi & 0 & \sin\phi \end{bmatrix}^T \begin{bmatrix} \Delta X_M \\ \Delta Y_M \\ \Delta Z_M \end{bmatrix}$$
$$\begin{bmatrix} \Delta X_M \\ \Delta Y_M \\ \Delta Z_M \end{bmatrix} = \begin{bmatrix} X_M \\ Y_M \\ Z_M \end{bmatrix} - \begin{bmatrix} R\cos\phi\cos\lambda \\ R\cos\phi\sin\lambda \\ R\sin\phi \end{bmatrix} \quad (1)$$

where (X_M, Y_M, Z_M) are coordinates of a point in the MBF coordinate system; (X_R, Y_R, Z_R) are the coordinates of the same point in the LSL frame; (Φ, λ) represent the latitude and longitude of the Spirit lander, which were reported as (14.5692°S, 175.4729°E). R is the radius of Mars at the lander (distance from the lander to the Mars center). In practice, R can be derived from the HiRISE DEM or from the MOLA points near the lander. Basically, Equation 1 effects a transformation of the vector (ΔX_M, ΔY_M, ΔZ_M) between the point and the lander from the MBF frame to the LSL frame. Using this transformation, the HiRISE orthophoto is defined in the same frame (LSL) as the Spirit traverse.

/* References */

1. Li, R., S. He, Y. Chen, M. Tang, P. Tang, K. Di, L.H. Matthies, R.E. Arvidson, S.W. Squyres, L.S. Crumpler, T. Parker, and M. Sims 2011. MER Spirit Rover Localization: Comparison of Ground Image- and Orbital Image-based Methods and Science Applications. Journal of Geophysical Research-Planets, Vol. 116, E00F16, doi:10.1029/2010JE00377.

2. Hwangbo, J. 2010. Integration of Orbital and Ground Imagery for Automation of Rover Localization, Ph.D. dissertation, The Ohio State University, Columbus, Ohio, 214 p.