Registration and its Uncertainty of MOLA Profiles with MOC Stereo Images

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1. Introduction

The high resolution instruments on board the Mars Global Surveyor (MGS) provide the necessary data to survey the Martian topographic surface in the finest detail so far [Albee, et al, 2002]. However, control information is needed to geo-reference the data and their processing results. Registration of MOC (Mars Orbiter Camera) images with the MOLA (Mars Orbiter Laser Altimeter) is an efficient way to acquire control for photogrammetric processing [Kirk, et al, 2001]. This paper presents a method that registers a MOLA profile to a stereopair of MOC images and evaluates the uncertainty of this registration.

2. Methodology

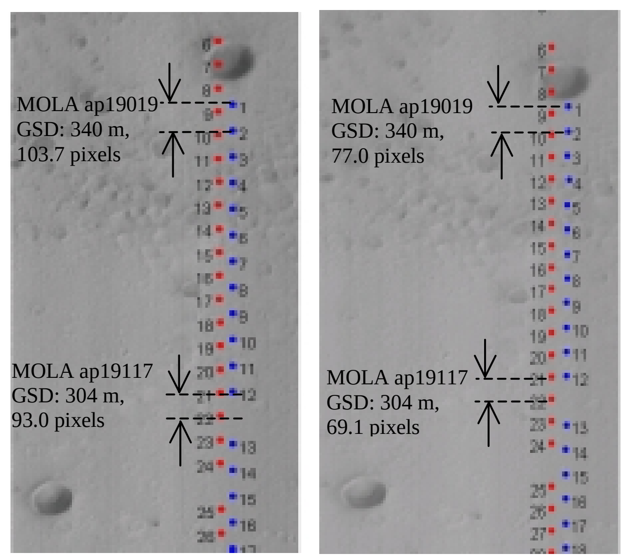
The methodology is based on the photogrammetric principle. Our objective is to associate every MOLA profile to all the images over the same area, including images collected simultaneously with the MOLA profile and images collected from a different orbit. Several complicated steps are involved in this process [Shan et al, 2002, 2003].

First, for each selected study area, an extent window is defined. This widow will be used to check against each MOLA footprint in all the available MOLA data archive (about 56 CD-ROMs). MOLA points in every orbit that are within the study area are then stored separately as a MOLA profile for the further processing. The second step is to obtain the MOC pointing and position data from the SPICE kernels. Based on the acquisition time of each MOC image, extraction and calculation are performed to obtain the MGS position and pointing. This is further processed together with MOC instrument calibration data to obtain the pointing of MOC images. In the third step, MOC position and pointing are modeled as a second-order polynomial of time to facilitate the photogrammetric calculation. This polynomial is determined by using the data extracted from the SPICE kernels at 30 time instants equally spaced at the MOC image. The last step is to project each MOLA profile onto every MOC image in the stereo pair. This is based on the collinearity equation [Shan et al, 2002]. An iterative approach is developed for this purpose. Our tests show that it converges 4-5 times faster and is more robust than the classical approach [Shan et al, 2003].

This methodology has several distinctions. First, it can register multiple MOLA profiles to multiple images over the same area. In other words, one MOLA profile can be registered to more than one image. Therefore, the comparison of the projected image features on the images will indicate the registration precision. Second, this approach is based on the 3D coordinates of MOLA points. Because of this, after registration each MOLA point will be found its corresponding locations on the MOC images. They can then be used as ground control points of certain uncertainty for downstream mapping processing. Third, the registration approach does not explicitly need the calibration information between MOLA and MOC instruments. By using a properly extended mathematical model, one can determine the MOC-MOLA instrument calibration.

3. Results and analysis

Three of the candidate landing sites are selected as our test areas. Each area is covered by two MOC images of a stereo pair. MOLA profiles collected simultaneously with the two MOC images are used for this study. Figure 1 shows the two registered MOLA profiles overlaid with the two MOC images in Isidis area. The MOLA sequential point numbers are labeled beside the MOLA points for the convenience of interpretation.



Left: E02-01301 Right: E02-02016

Figure 1. MOLA footprints registered on the stereo pairs (Isidis Planitia)

Figure 1 reveals some important properties of the MGS mapping data. First, the projection of a MOLA profile is nearly a straight line on the MOC images. This straight line is parallel to the flight direction and offset from the center of the image scan lines. The offset verifies the MOC and MOLA instrument boresight difference, which is documented in the SPICE kernels and considered in the ISIS package in the registration of MOLA profile to MOC images (Kirk et al, 2001). Second, a visual check by using the common image features as a reference indicates that the two projections of the same MOLA point on two images are inconsistent at the magnitude of one (1) MOLA ground spacing distance (GSD,

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~320m) along the flight direction, which corresponds to 69 to 104 pixels on the images, depending on image scale. For example, in Figure 1 point 6 of MOLA profile ap19117 (left profile on the images) on the left image is projected at approximately the same location as point 7 of the same profile on the other image. A similar observation can be made for point 16 on the left image and 17 on the right image. Analysis on the MOLA profile ap19019 yields the same conclusion. This reveals that the uncertainty of the two projections of one MOLA point on two images is about one (1) MOLA GSD, which is the MOLA-MOC registration inconsistency if no additional correction is applied. Finally, it is noted that the registration uncertainty remains more or less the same over the image regardless of the point location on the image. Therefore, one constant parameter per MOC image might be used to describe and correct this inconsistency between the projections of a MOLA profile.

This registration uncertainty is caused mainly by a combination of three error sources. The first is the uncertainty in associating a scan line to its correct exposure time instant. This in turn might be caused by the uncertainties in scan start time, exposure time per scan line, and the loss of scan lines in the image decompression process. The second is the uncertainty of sensor position and pointing derived from the SPICE kernels. The third is the error of the 3D positions of MOLA points, which are in turn derived from SPICE kernels, Martian geoid (areoid) model and MOLA range measurements. The quantitative contribution of each individual uncertainty source cannot be separated from the total uncertainty (~1 MOLA GSD) at this point without having sufficient knowledge about the magnitude of each uncertainty source. However, the constant behavior of the MOC-MOLA registration uncertainty suggests the possible dominant contribution from the scan line-time association error.

4. Conclusions

MOLA profile can be registered to multiple images over the same area. This will provide 3D ground control for the downstream photogrammetric processing of MOC images. The registration uncertainty is about one MOLA ground spacing distance, namely 320 meters, along the flight direction. Future work will be focused on the precision determination of the registration uncertainty by using extended registration model and the internal constraints in the MOC imagery.

5. References

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