Seamless Polar Mosaic Generation from Chandrayaan-2 TMC-2 DEM

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Abstract
We propose an improved (i.e. better vertical accuracy) and seamless TMC2 polar mosaic DEM at 10m/pixel for Polar region. In polar region we use co-registration of TMC2 DEM with highly accurate LOLA altimetric profiles (typically <10m horizontally &<1m vertically) for better accuracy. At cutline (i.e. overlap region) horizontal & vertical image blending applied if any radiometric mismatch appears. Due to poor illumination condition (i.e. low sun elevation) at polar regions the void (no height) appears especially at crater base & wall. These voids at TMC2 DEM are filled using polygon interpolation from global lunar mosaic LOLA raster and finally after filling voids all strips are seamlessly mosaicked for raster generation. Also statistically validated the improvement of vertical accuracy of the resulted TMC2 raster mosaicked DEM LOLA geodetic ground track beam spot points. This paper elaborates generation of TMC2 DEM polar mosaic and its validation.

Keywords DEM, seamless mosaic, LOLA track, topography

Introduction
Chandrayaan-2 (CH-2), India's second mission to the Moon, is an advanced version of the previous Chandrayaan-1 mission [1]. The Orbiter with scientific payloads is orbiting around the moon. The data coming from these payloads is processed and archived at ISSDC Bangalore. Same datasets are also archived at Space Applications Centre-Payload Operations Centre (SAC-POC) for higher-level data products generation. As part of the ground segment, a Data Processing Generation system for Chandrayaan-2 payloads was developed at SAC and is deployed at ISSDC towards realizing the mission goals of Chandrayaan-2. Data Processing (DP), SAC has designed, developed and operationalized various software packages for processing the data from optical sensors viz. TMC2, IIRS, and OHRC through Data Products Generation System (DPGS). DPGS processes, generates and archives the data products in Planetary Data System (PDS4) [2].

Digital elevation models (DEMs) are an important information source for spatial modelling. TMC2 is a triplet stereo sensor of CH2 mission which generates lunar DEM for both polar & equatorial regions in Fore-Aft-Nadir (FAN) combinations [1]. Seamless mosaic DEM generation for both Polar & Equatorial regions are essential requirement towards lunar topographic analysis. However, it is observed that there are many full strip DEM where the voids which otherwise called no height values commonly exists at lunar craters and at highly undulating surface results an incomplete DEM product, and thus significantly degrade DEM data quality and usability. These voids mainly occur in polar regions due to shadow/occlusion which is indirectly due to poor illumination condition at the Poles. This results an incomplete lunar mosaic generation and topography analysis. Therefore, there is a requirement to develop an algorithm to generate seamless TMC2 mosaic DEM generation towards science study.

Objective

The main objective is to develop an algorithm to fill voids or no height values in shadowed or poor illumination areas in TMC2 DEM at polar regions using altimeter-based LOLA DEM. Also to carry out the validation of TMC2 void filled DEM w.r.t. external lunar global reference like LOLA, SLDEM and WAC GLD DEM [3]. Other than polar regions the exercise is carried out at equatorial regions to validate algorithm. Finally, after filling voids at polar region for all strips, this data used to generate seamless polar mosaics.

Input Data:

TMC2 DEMs: It is topographic representation of lunar surface containing height value at each fixed grid interval. It has a resolution of 10 m that is obtained from the stereo triplet intersection taking input as a conjugate point from triplet matching of TMC2 along track stereo sensors i.e. Fore, Aft, Nadir (FAN) of CH-2 [2]. For a showcase the footprints of a few polar data covering ± 60 to ± 90 deg. latitude of TMC2 DEM shown in Figure [1].

LOLA DEM: It is a laser altimeter-based raster DEM available as a global lunar mosaic having

a. Resolution of 30 m, from ± 60 to ± 90 deg. Latitude and 0 to 360 deg. Longitude [3].
b. Laser beam spot has vertical accuracy of ~ 1m in moon ellipsoid [3].

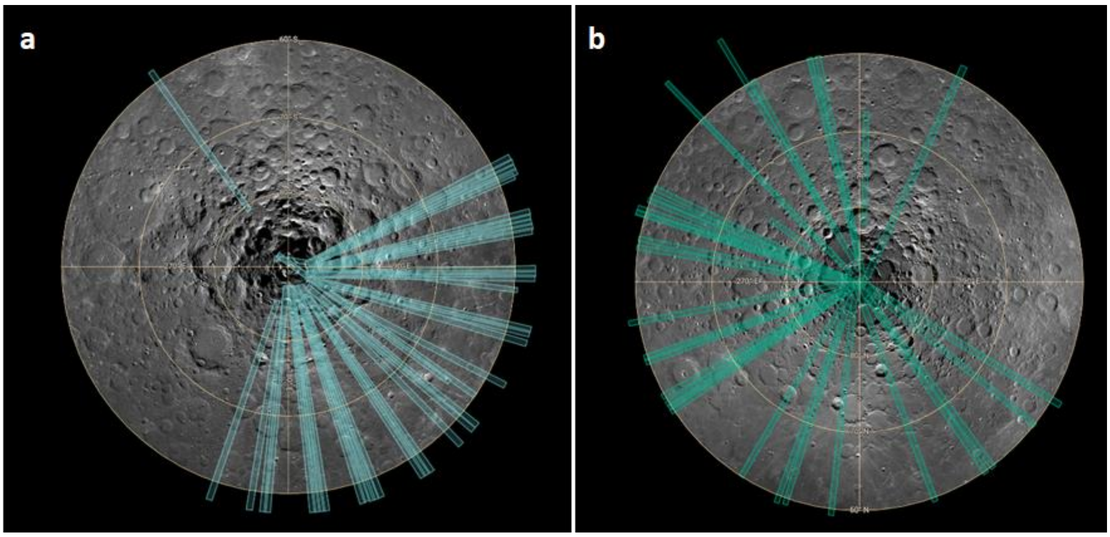

Fig. 1 Footprints of few TMC2 input data at (a) south pole and (b) north pole.

Methodology

The inputs taken for this algorithm are the TMC2 FAN DEM having voids and the corresponding extracted LOLA reference. The following steps are followed to implement the methodology:

1. Extract LOLA strip from LOLA global mosaic using TMC2 DEM corner coordinates.
2. Applying 3-D registration between TMC2 & LOLA point clouds for alignment [3].
3. Resize the TMC2 DEM to the resolution of the reference LOLA DEM i.e. 30m pixel size.
4. Generate mask from TMC2 DEM to demarcate void and non-void areas using masking polygon.
5. Extract the common area i.e. polygon from the LOLA reference using the mask.
6. Fill the void polygon in the TMC2 DEM from the extracted LOLA DEM.

7. Smoothen radiometric imbalance between void & non-void in void filled TMC2 DEM polygon using weighted average (blending).
8. Validate topography of void filled TMC2 polar DEM w.r.t. reference LOLA DEM.

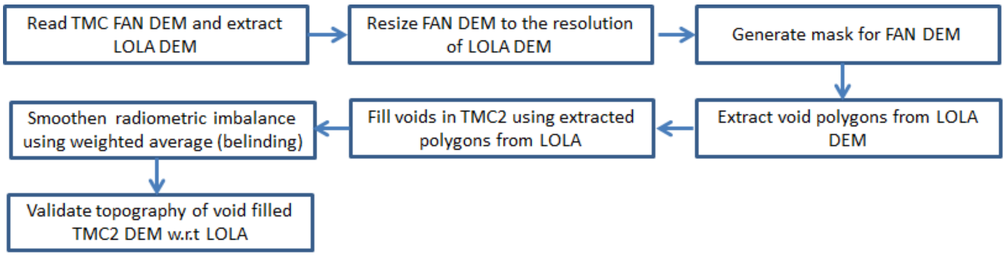

Fig. 2 Flow diagram of TMC2 DEM void filling methodology

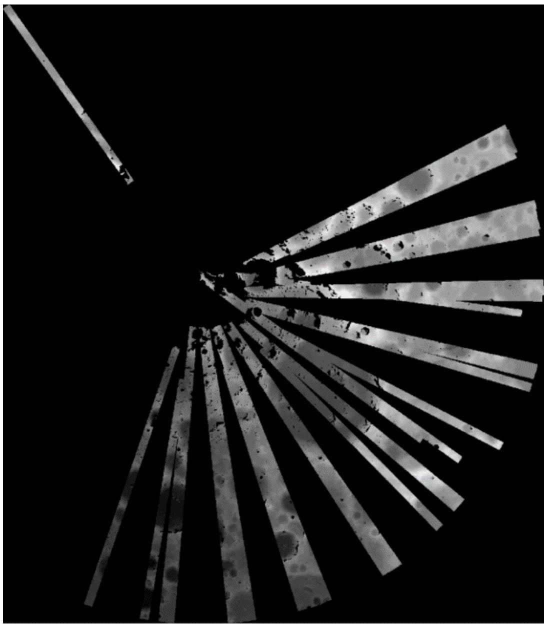

Fig. 3 TMC2 DEM before void filling at south pole from latitude 60S to 88S.

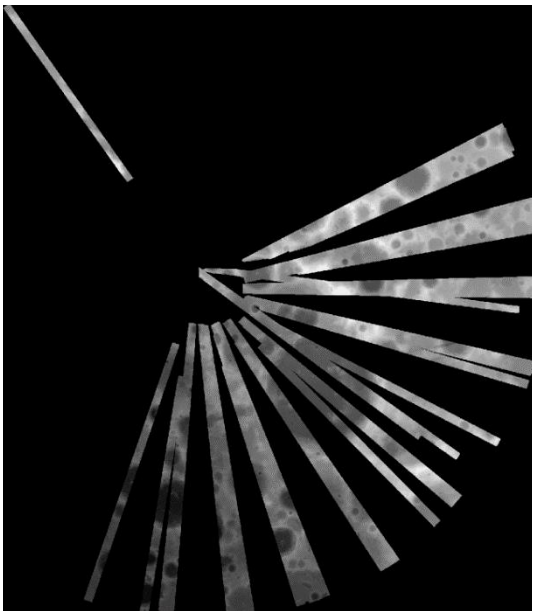

Fig. 4 TMC2 DEM after void filling at south pole from latitude 60S to 88S.

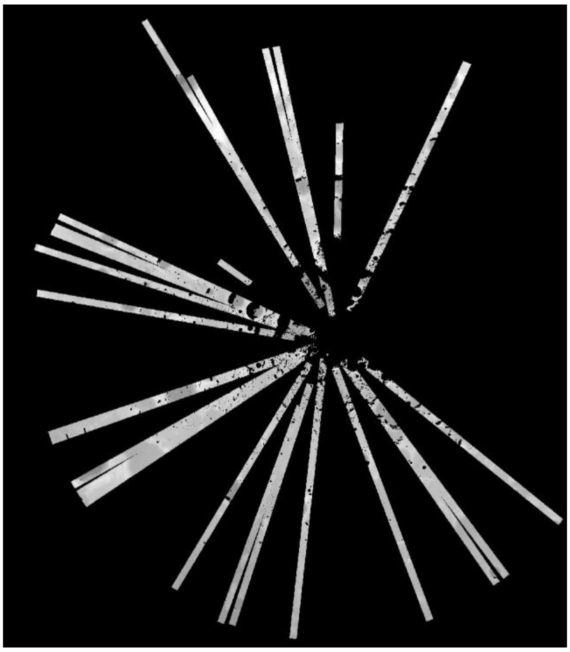

Fig. 5 TMC2 DEM before void filling at north pole from latitude 60N to 88N.

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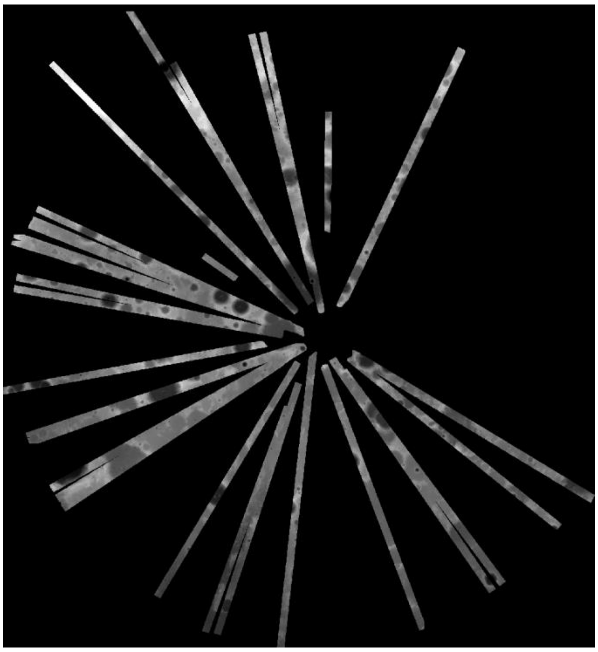

Fig. 6 TMC2 DEM after void filling at north pole from latitude 60N to 88N.

As test case, few orbits are selected for implementation & testing of algorithm and the results are shown in Figures [3,4,5,6] indicating comparison before and after void filling of both north & south pole. Also it shows that all polygons marked as void and correctly filled w.r.t LOLA over a full strip data. For one orbit, a crater is selected and elevation profile is compared w.r.t LOLA as shown in Figures [7,8]. This shows that topography profile is having matching variations w.r.t reference. In Figure [8], red & blue graph shows topography profiles before and after void filling of same crater in FAN DEM. Similar observations are also seen during visual inspection before & after void filling at few selected craters for more north & south pole full strip data sets. Finally 3-D registration and void filling applied for all polar data acquisition of TMC2 DEM till imaging season 7 (i.e. February 2023) and merged all the strips towards seamless mosaic generation Figure [9ab]. Since there are still gaps visible between orbital strip shown in Figure [9ab] and as optical season emerges and data acquisition continues for polar region (north & south) then this methodology can be applied for void filling and mosaic generation.

Fig. 7 TMC2 DEM before & after void filled topography line (red mark).

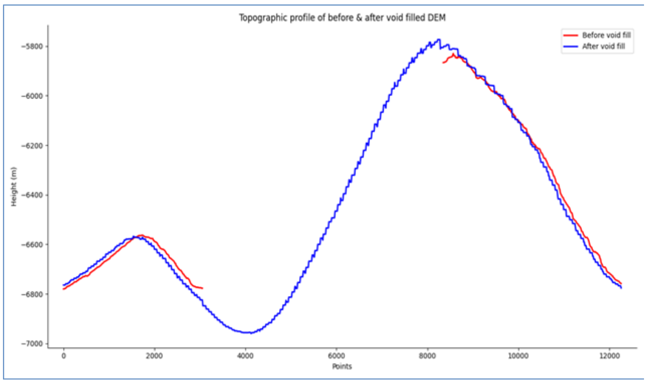

Fig. 8 Topography profile comparison before & after void filling.

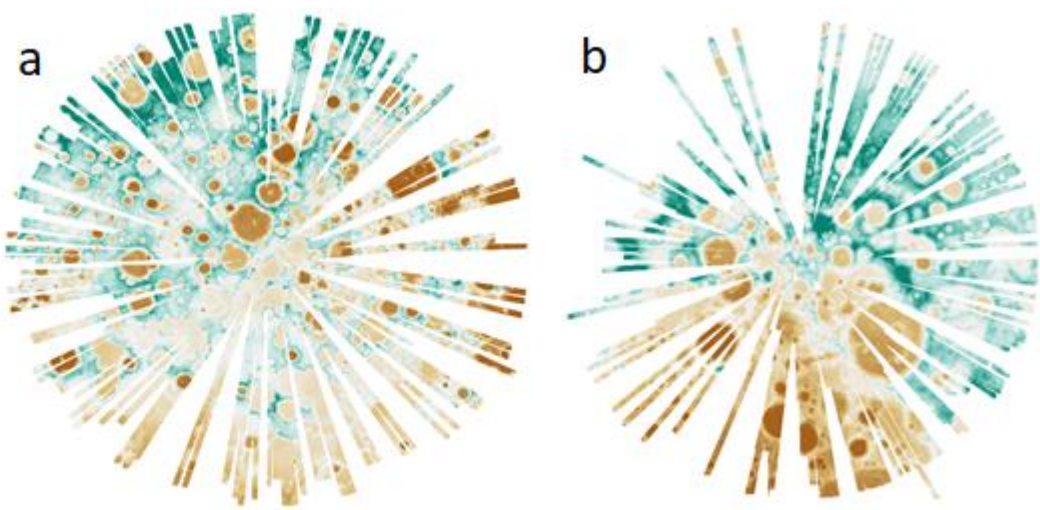

Fig. 9 (a) North pole mosaic from latitude 60N to 90N. (b) South pole mosaic from latitude 60N to 90N.

Conclusions

An algorithm is developed and tested using multiple polar (north & south) TMC2 DEM for filling void or no height values of full strip data and mosaicking. A software is developed in Python language for testing the algorithm. From exercise it is observed by comparing topography, the polygon-based voids are filled correctly for full each full strip data. After filling voids, all the strips are mosaicked and verified w.r.t. LOLA raster to validate/evaluate the topography. It is found that the elevation points are correctly matching w.r.t. reference topography profile. Also, from visual inspection of multiple data strips it is observed that, at void polygon the elevation value does not have any radiometric imbalance compared with non-void areas. Therefore, one can conclude that at poor illumination region (polar) the TMC2 DEM can be used for science study by filling void polygon from external global lunar altimeter data source. And this TMC2 DEM polar mosaic data having better resolution (posting) can be used as elevation reference and lunar topography analysis. Currently data acquisition is continuing, therefore, future activity is aimed to generate full seamless polar mosaic once complete polar data is acquired and available.

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