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Digital Elevation Models of the Lunar Surface from Chandrayaan-2 Terrain mapping Camera-2 (TMC-2) Imagery – Initial Results

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Introduction: The Indian second moon mission Chandrayaan-2 was launched on 22 July 2019. The spacecraft reached the moon's orbit on 20 August 2019 and began operations successfully. Terrain Mapping Camera-2 (TMC-2) is one of the 08 payloads onboard Chandrayaan-2 orbiter that will provide 3D mapping of moon. It is a line scanner similar to TMC of Chandrayaan-1 with three CCD arrays, Fore, Nadir and Aft looking at +25, 0 and -25 degrees respectively and provides three images (triplet) of the same object with three different view angles [1]. The swath and resolution of TMC are 20km and 5m, respectively. The specifications of TMC-2 are provided in table-1. The 5 m resolution of the Chandrayaan-2 camera will provide the global stereo coverage with highest spatial resolution of all the lunar missions so far. The camera works in the visible region of the electromagnetic spectrum.

The objective of this paper is to (i) test the capability of Chandrayaan-2 TMC-2 images for DEM generation towards Lunar three dimensional mapping and (ii) to provide the initial results of Digital Elevation Model (DEM) from TMC-2 triplet. DEMs are important and are valuable tools for scientific analysis of lunar surface geology and large scale geomorphology. Algorithms used for Earth-based imaging are often inadequate, as they assume that accurate ground point (surveyed) coordinates or GPS derived platform coordinates are available. The reference system considered for the moon topographic coordinates are based on ME/PA (Mean Earth Polar Axis) system which is also known as selenographic system. ME/PA is a right handed Cartesian coordinate system having origin as Centre of mass of moon. The selection of reference coordinate system is based on the lunar reference datasets as most of the lunar datasets (Like Selene, LOLA , LRO-NAC and LRO-WAC) are available in the same reference system.

Table-1. specifications of TMC-2

Parameter	TMC-2
Altitude (km)	100
Spatial Sampling (m)	5 m
Swath (km)	20
Stereo mode	3-views along track, B/H=1
Spectral range (μm)	0.50 – 0.85
Quantization (bits)	12 bit (10 bit reception)
Gain/Exposure	4 - Exposures and single gain

Datasets Used: For carrying out Stereo processing of Chandrayaan-2 TMC-2 images, three areas featuring different surface characteristics have been chosen (table-2).

Table-2: Test Data Sets Used

S. No.	Orbit	Date of Pass	Centre Coordinates	
			Latitude	Longitude
1	628	15-10-2019	00.4666N	53.4545E
2	1302	09-12-2019	15.2926N	43.2691E
3	1315	10-12-2019	15.3848N	30.0976E

Types of Data Products available: TMC-2 datasets are available in three level of processing (L-0, L-1 and L-2). Level-2 products contain the Digital elevation model and Orthoimage which is generated from Level-1 product (Radiometrically corrected and seleno-tagged product) as an input. All the datasets are available in PDS-4 standard.

Reference Datasets used for Lunar Control Points (LCPS): Selene Ortho-images for position and LOLA DEM for altitude have been used for LCPS. In case of non-availability of LCPs from Slelene, LRO-WAC / Clementine will be considered for the LCP identification [2] [3].

DEM Generation Methodology: A schematic of the workflow for DEM generation is shown in figure 1. The production and quality control of DEMs and ortho-images are carried out using an indigenous Level-2 product generation software. The DEM generation process implemented in the software involves Image matching between the suitable two or three images of the triplet, Lunar Control Point (LCP) identification, resection, intersection, irregular DEM points generation and regular DEM and corresponding Ortho-Image generation using Interpolation. DEM is generated using the mass points obtained from automatic matching process. First, we extracted the exterior orientation of the two images in a stereo pair from Chandrayaan-2. Intersection is then

performed to determine the 3D coordinates of the matched corresponding points. Once the 3D locations of image points have been determined, the 3D points are interpolated using a triangle mesh interpolant. This mesh is then sampled at regular intervals in latitude and longitude. The elevation determined is based on a Vertical datum which is based on spherical figure of the Moon and a lunar mean radius of 1737400 m.

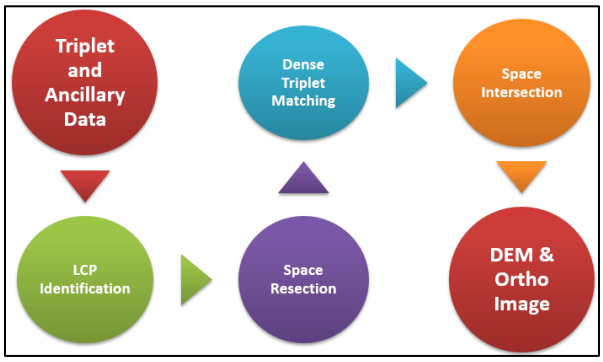

Figure-1: Workflow for DEM Generation process

Results: The DEMs and Ortho-images from Chandrayaan-2 TMC-2 datasets are getting generated in an operational manner. The overview of initial results of three such orbits are presented in figures-1,2,3 and 4. All the three Orbit DEMs are compared with LOLA independent height points references. The TMC-2 DEMs RMS error with respect to LOLA DEM points have been found within 25m for all the three cases. This DEM accuracy is far better than Chandrayaan-1 TMC DEM where the RMS error was 100m. The improvement in TMC-2 DEM is mainly due to use of better lunar control points and geometrical modeling.

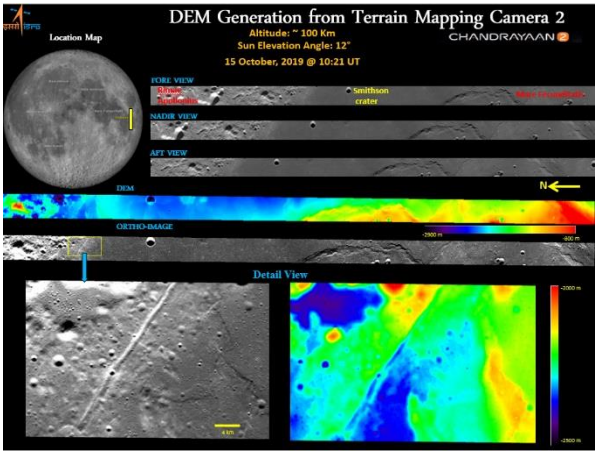

Figure-2: DEM and Orthoimage Generated for Orbit no. 628 of TMC-2 datasets

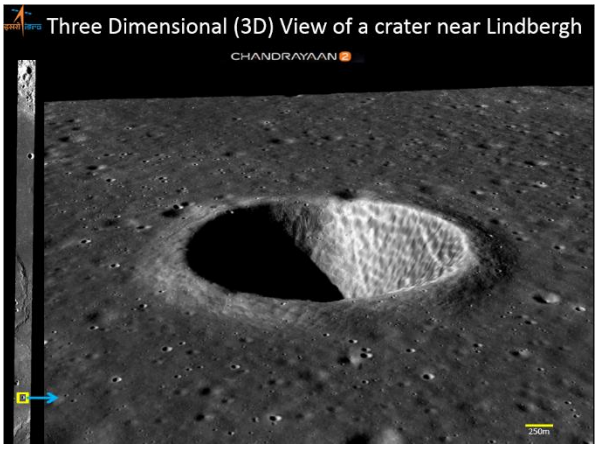

Figure-3: 3D view of a crater from the generated DEM of Orbit no.628 of TMC-2 datasets

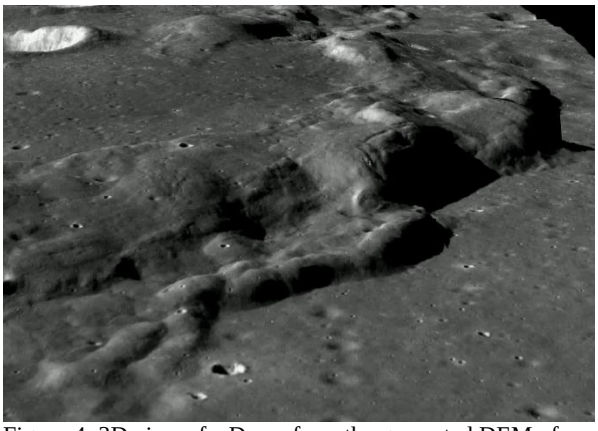

Figure-4: 3D view of a Dorsa from the generated DEM of Orbit no.1305 of TMC-2 datasets

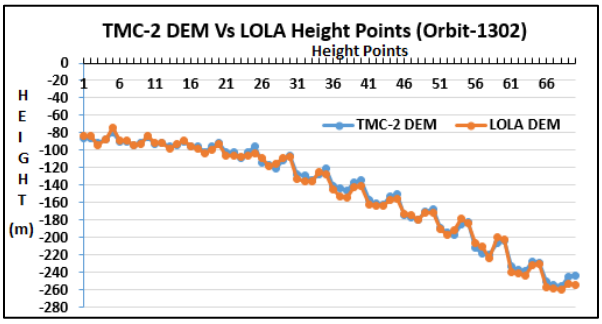

Figure-5: TMC-2 DEM comparison of Orbit no.1302 with LOLA heights values

References: 1. DEM of Lunar Surface from Chandrayaan-1 TMC Imagery,Abstract # 1694, 40th LPSC-2009; 2. https://www.lroc.asu.edu; 3. http://www.kaguya.jaxa.jp

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