Triplet Camera based Digital Elevation Model Generation of Lunar Surface from Chandrayaan-2 Terrain mapping Camera-2 (TMC-2) Imagery – Quality Improvements and Results

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Introduction: The India's second mission to moon Chandrayaan-2 was launched on 22 July 2019 and reached moon's orbit on 20 August 2019.Terrain Mapping Camera-2 (TMC-2) is one of the 08 payloads onboard Chandrayaan-2 orbiter that provides the ability of 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 geometric arrangement of triplet camera is illustrated in fig.-1.

The objective of this paper is to (i) demonstrate the capability of Chandrayaan-2 TMC-2 triplet images for Digital Elevation Model (DEM) generation using two and three camera images and (ii) to provide the details of quality improvements incorporated in the DEM generation process and results. DEMs play an vital role and are valuable tools for scientific analysis of lunar surface geology and large scale geomorphology. Since, the feature on the ground is imaged by three different view of the camera, it inturn reduces the requirements of no.of control points for geometric modelling. The fig.-2 shows the crater image as viewed by three different views of the camera.

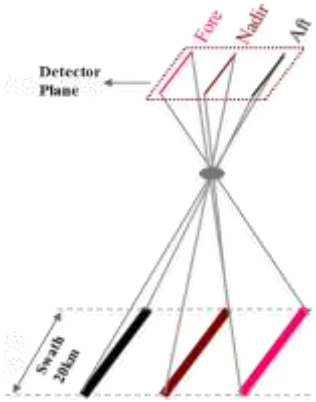

Figure-1: Geometric Arrangement of Triplet Camera

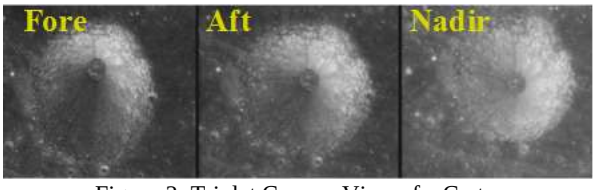

Figure-2: Triplet Camera View of a Crater

Datasets Used: For carrying out DEM generation using Chandrayaan-2 TMC-2 triplet images, five areas featuring different surface characteristics have been chosen (table-1).

Table-1: Test Data Sets Used

S. No.	Orbit	Date of Pass	Center Coordinates	
			Latitude	Longitude
1	1731	13-01-20	-14.846	302.534
2	1755	15-01-20	-15.404	275.274
3	2032	07-02-20	-15.609	339.031
4	2048	08-02-20	-16.015	319.362
5	2060	09-02-20	-16.404	306.221

Reference Datasets used for Lunar Control Points (LCPS): Selene Ortho-images are used as planimetry reference and LOLA DEM are used as height reference in LCPS. In case of non-availability of LCPs from Selene, LRO-WAC / Clementine will be considered for the LCP identification [2] and [3].

Triplet DEM Generation Improvements: A detailed explanation on generic DEM generation methodology using TMC-2 dataset is described in [1]. For triplet DEM generation, common control points need to be auotomatically identified across fore,aft and nadir images from reference image as shown in fig.-3 for geometric modelling and accurate height estimation.

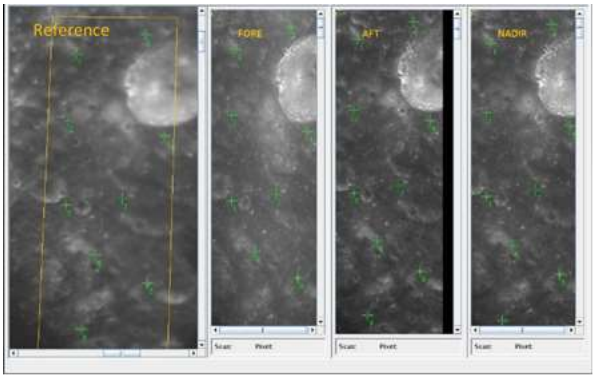

Figure-3: Control Point Identification on Triplet Images

After control point identification triplet image matching is done to estabilish a relationship between all the three view of the camera. Since there are shadow and brighter

regions in craters and other lunar surface features, image matching results is inaccurate results on those areas, which results in artefacts in DEM.It has has been mitigated by segmenting long strip of image into no.of small segments. The artefacts are reduced from ~10% to <1% as shown in fig.-4.

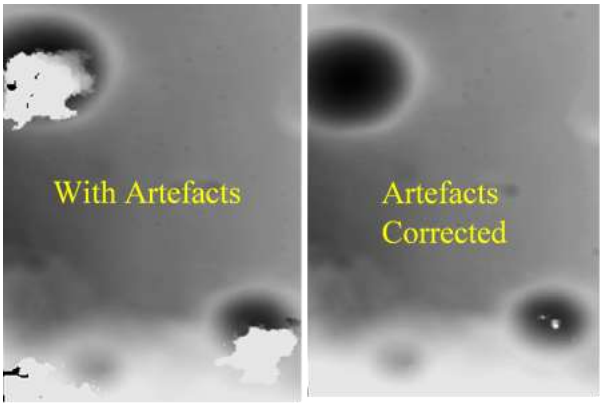

Figure-4: DEM with and without Artefacts

By doing triplet image matching, artefacts are greatly reduced and accuracy of the DEM is also improved. TMC-2 gives an oppurnity to generate DEM using the combination of Nadir-Fore, Nadir-Aft and Fore- Aft-Nadir. All the three combinations are experimented and best possible accuracy is achieved using Fore-Aft-Nadir combination. Nadir-Fore and Nadir-Aft combination DEM will have more ground coverage than triplet combination as shown in fig.-5, whereas triplet DEM will have the best accuracy of all.

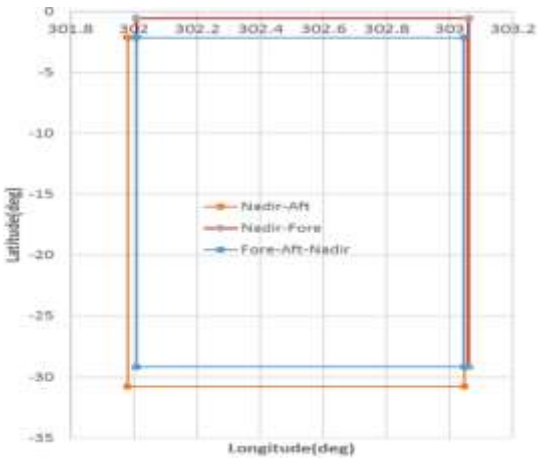

Figure-5: DEM Ground Coverage for Different Combinations

Results: The DEMs and Ortho-images from Chandrayaan-2 TMC-2 datasets are getting generated in an automatic manner for Fore-Aft-Nadir combinations at 10m grid spacing. It was seen from the experimentation that the fore-aft-nadir combination based DEM generation brings out more details than nadir-fore and nadir-aft combinations as shown in figure 6.

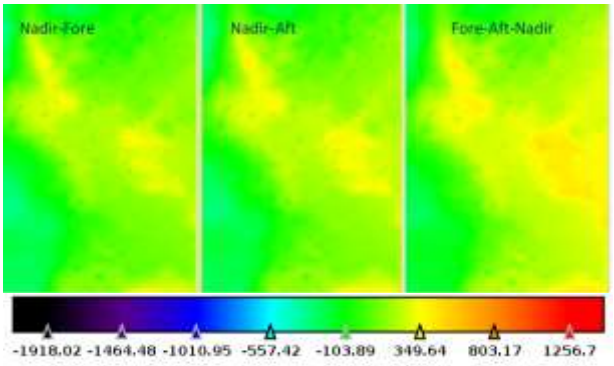

Figure-6: DEM from Different Combinations

Accuracy assessment on different combinations of DEM with respect to LOLA DEM is presented in the table 2. Fore-aft-nadir combination gives the best height accuracy compared to other combinations.

Table-2: Height Accuracy Assesment

S.No	Orbit no.	Date of Pass	Nadir Fore Height RMS Er-ror(m)	Nadir Aft Height RMS Er-ror(m)	Fore Aft Nadir Height RMS Er-ror(m)
1.	1731	13-Jan-20	18.79	27.58	7.88
2.	1755	15-Jan-20	8.01	8.42	7.16
3.	2032	7-Feb-20	7.91	7.41	6.50
4.	2048	8-Feb-20	11.69	9.73	9.12
5.	2060	9-Feb-20	8.10	7.05	6.91

The overview of a crater (ortho and DEM combined with color coding) for orbit no. 1731 is shown in fig.-7.

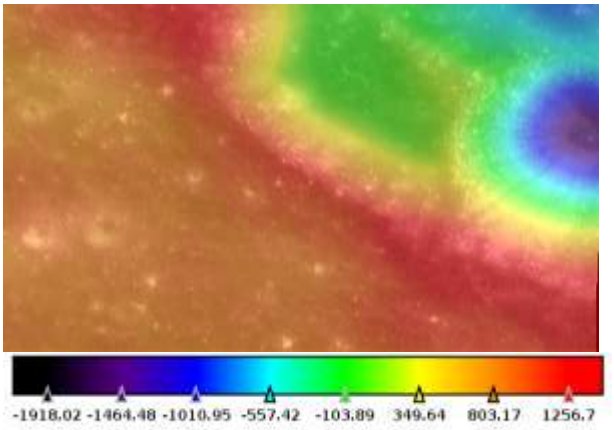

Figure-7: DEM from Different Combinations

References: 1. Digital Elevation Models of the Lunar Surface from Chandrayaan-2 Terrain mapping Camera-2 (TMC-2) Imagery – Initial Results,Abstract # 1694, LPSC2020;2.https://www.lroc.asu.edu;3.http://www.kaguya.jaxa.jp