DIGITAL ELEVATION MODELS OF THE LUNAR SURFACE FROM CHANDRAYAAN-1 TERRAIN MAPPING CAMERA (TMC) IMAGERY – INITIAL RESULTS

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Introduction: The Indian moon mission Chandrayaan-1 was launched on 22 October 2008 and it began operations successfully on 14 November 2008. Terrain Mapping Camera (TMC) is one of the 11 payloads onboard Chandrayaan-1 that will provide 3D mapping of moon. It is a line scanner with three CCD arrays, Fore, Nadir and Aft looking at +26, 0 and -25 degrees respectively and provides three images (triplet) of the same object with three different view angles. The swath and resolution of TMC are 20km and 5m, respectively. The specifications of TMC are provided in [1]. The 5 m resolution of the Chandrayaan-1 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-1 TMC images for DEM generation towards Lunar mapping and (ii) to provide the initial results of Digital Elevation Model (DEM) from TMC triplet. DEMs are important and are valuable tools for scientific analysis (e.g., 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. There are two geometric models which can be used for correcting Chandrayaan -1 data: the rigorous method and the rational polynomial coefficient (RPC) method. Both the Geometric models depend on the orbital parameters. The RPCs are specially generated for the purpose of geometric modeling. Unlike Earth, most other bodies in our solar system are defined with a positive-west longitude system and most GIS and remote sensing applications cannot handle this longitude system. We used a positive-east longitude system for our digital Raster and Vector layers, but for output we use the positive-west convention for referencing and labeling.

Datasets Used: For carrying out Stereo processing of Chandrayaan-1 images, three areas featuring different surface characteristics have been chosen (table-1).

Table-1: Test Data Used

S. No.	Crater / Area	Co-ordinates (in deg)			
		Upper left		Lower right	
		Lat	Long	Lat	long
1.	Part of Moretus	-1.40	-70.60	-0.30	-72.68
2.	Coulomb	248.13	62.29	249.27	02.80
3.	Part of Mare Orientale	263.76	-21.94	264.48	-29.95

Type of Datasets: (a) Data Product Type: Level 1, (b) Geometric Processing Level: Radiometrically corrected product (c) Raster data Format: GEOTIFF, (d) No. of Bands: 1 (Panchromatic).

Clementine global mosaic [2] and ULCN2005 [3] are taken as reference for sensor orientation.

Methodology: A schematic of the workflow for DEM generation is shown in figure 1. The production and quality control of DEMs and orthoimages are carried out in LPS general-purpose digital photogrammetric workstation (DPW) environment. The DPW provides a complete workflow, including (a) Modules for multi-sensor triangulation, (b) Automatic stereo matching using the automatic terrain extraction (ATE) module to generate DEMs, (c) Quality control and DEM editing using the interactive terrain editing (ITE) module.

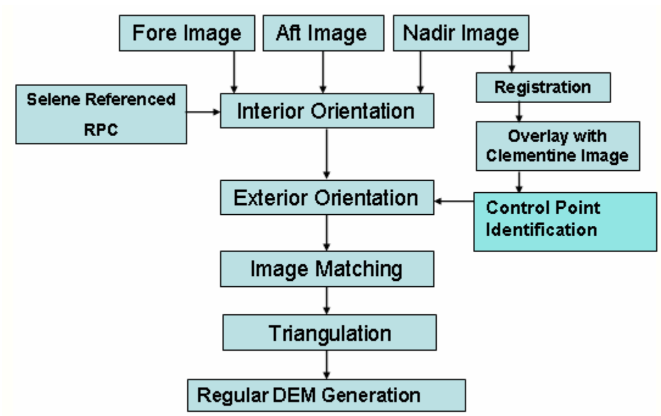

Figure-1: Flow diagram of Methodology adopted.

DEM Generation: 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-1. 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. Vertical datum is based on spherical figure of the Moon and a lunar radius of 1737400 m. All elevations thus generated are in meters and represent the true values as the input ULCN points. These calculations are performed under the IAU 2000 Cartesian coordinate system.

Results: There are four possibilities of stereo image processing for the DEM generation. The combinations are (a)

Fore and Aft, (b) Fore-Nadir, (c) Aft-Nadir and (d) Fore-Aft-Nadir images as a pair. Except Fore-Aft case all other cases have produced a well distributed conjugate points. As per the statistics of the match points (table-2), between Fore-Aft image matching the point matching success rate was 27 percent while the pattern-matching rate between the two images was only 14 percent. Due to these poor results it has generated only 700 conjugate points and consequently a large number of points were failed to produce the correct elevation. The poor image matching may be due to the large angle difference (nearly 50 degree) between the two images. The three camera triplet image (Fore-Aft-Nadir) produced the best matching results with 100% success in point matching while nearly 87% success in pattern matching. Five Lunar control points were used for modelling the Moretus crater strip, while it was racy on Moretus area for the five points in X, Y and Z is 25 m, 47 m and 227 m respectively. In case of triplet, bundle adjustment technique has been used for the modelling of triplet conjugate points.

In the case of Coulomb crater area, the full pass images are divided into 3 strips of 600 km each in the along the track and DEMs have been derived for all the three strips individually. A small portion of this DEM (containing the full crater) is shown in figure-2 along with the orthoimage, color coding and 2.5 D visualisation. Figure-3 gives the DEM for a part of Moretus crater along with its color coded view and orthoimage. Figure-4 shows the color coded DEM for a part of Mare orientale along with its orthoimage.

Table-2: Conjugate Point Statistics-Moretus Crater

S. No.	Pair	NIPT/ NPR	No. of match points	Point Suc. Rate	Pattern Suc. Rate
1.	F-A	3008	823	27.36	14.49
2.	F-N	3008	4953	100	70.38
3.	A-N	3008	5276	100	74.88
4.	F-A-N	3008	7905	100	86.14

F: Fore, A: AFT, N: Nadir, NIPT: No. of intended points, NPR: No. of patterns

Conclusions: The initial results demonstrate the possibility to derive relatively accurate DEMs from Chandrayaan-1 TMC imagery. Three CCD imagery in the triplet form, when compared to stereo pair leads to a good DEM in terms of detail due to the better point and pattern matching accuracies. The DEMs at 25 m grid will be a prime input for science analysis along with data from the other payloads on board Chandrayaan-1 such as HySI, M3 and MiniSAR.

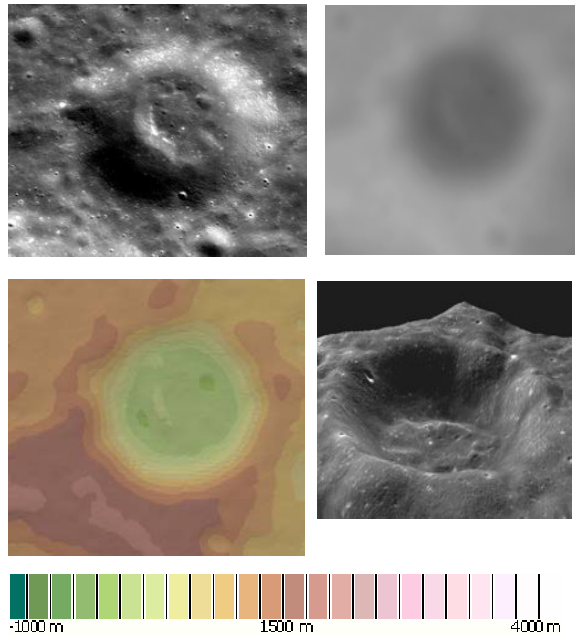

Figure-2: Coloumb C Crater, DEM and visualisation

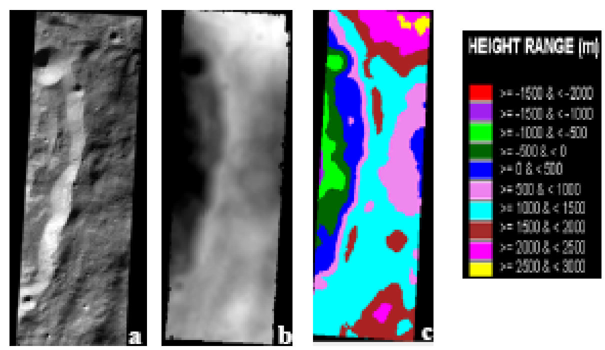

Figure-3: Part of Moretus Crater (a) Orthoimage (b) DEM (c) Color coding (20 km x 60 km long)

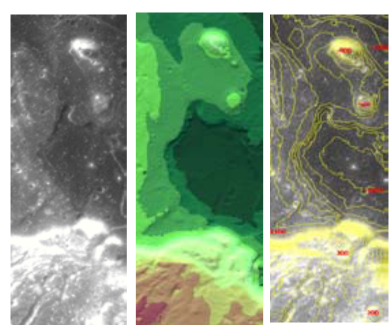

Figure-4: Part of Mare Orientale. (a) Orthoimage (b) Colour coded DEM (20 km x 60 km long) (c) Contour Image

References: [1] Kiran Kumar A.S., et al (2009) Current Science in press.
[2]//webgis.wr.usgs.gov/download/ClementineUVVIS/Mosaic
[3]//webgis.wr.usgs.gov/download/ClementineUVVIS ULCN2005.warp