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Creation of Digital Elevated Model using lunar images of Chandrayan-1

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Abstract

The present work discusses the technique and methodology of analysing and Terrain Mapping Camera (TMC) Images acquired during India's first Moon mission, Chandrayaan – 1, launched on October, 2008 for generating Digital Elevated Model (DEM). The Terrain Mapping Camera (TMC) on India's first satellite for lunar exploration, Chandrayaan-1, is intended for systematic topographic mapping of the entire lunar surface, including the far side and the polar regions. A high resolution imagery of the entire Moon will help detailed study of specific lunar regions of scientific interests and further our understanding of lunar evolution. The swath of the instrument is 20 km. The digital elevation model (DEM) is a computer representation of the moon's surface. DEMs can be generated by traditional photogrammetry based on aerial photos if they are available and they are created very often more economically by the means of space images. A Digital Terrain Model (DEM) is a continuous representation of a ground surface landform that is commonly used to produce topographic maps. DEMs are created by integrating data obtained from a wide range of techniques including remote sensing and land surveying. DEM's are sampled arrays of elevation values representing ground positions at regularly spaced intervals. Digital Elevation Model (DEM) is the terminology adopted by the USGS to describe terrain elevation data sets in a digital raster form. The normal orientation of data is by columns and rows. In this project work a DEM is created for each of the lunar images retrieved from the space craft using Triangulated Irregular Network (TIN)

Keywords: *Chandrayaan-1, DEM, Swath, TMC, TIN*

1. Introduction

The possibility to store and analyze 3-D real world data in digital form has become reality in many fields of human activity. More detailed information and data about the environment can now be sought, analyzed and presented as the digital data storage and manipulation capacities has increased and are made available. Accurate data collected with cost-efficient methods is always useful in planning and decision making. Fifteen to twenty years ago, accurate 3-D photogrammetry required highly sophisticated and expensive equipment together with trained personnel for many of its routine tasks. Now, with digital imagery, at least the demand for the special equipment has changed dramatically. Technical advancements in laser and positioning technology have also provided us with new ways of looking at the world.

Photogrammetry is based on the processing of images. The main products of Photogrammetry are Digital Elevation Models (DEM), Digital Surface Models (DSM), Orthoimages, 2D and 3D reconstruction and classification of real world objects, and visualization (virtual models). Although many photogrammetric theories date back more than a century the use of digital photogrammetry in extracting information has undergone only development for the last 20 years. The degree of automatization and digitalization of the processing work is now quite high. Information on the nature, extent, spatial distribution, potentials and limitations of natural resources is a pre-requisite for various developmental activities. Though topographical maps provide some spatial information about natural and cultural features of the terrain, apart from geographical location, it is not adequate enough for developmental planning.

Aerial photographs and satellite data have, therefore, been used to generate such information. With the world of computer technology and the rapid development of 3-D visualization technology into the traditional static two-dimensional map of the three-dimensional terrain modeling makes a Geographic Information System (GIS) and digital mapping, a new field of study. Understanding the topography of the Moon is an important issue for further lunar exploration. It is a key factor for choosing land sites, setting up lunar observation stations and developing exploration activities in the future. DEM is the basis of geographic information system data, mainly used to describe the ground state of ups and downs, the terrain can be used to extract various parameters such as slope, aspect, roughness.

The DEM file is not a scanned image of the paper map (graphic). It is not a bitmap. The DEM does not contain elevation contours, only the specific elevation values at specific grid point locations. A proper representation of the surface of the moon is needed as a data source for modeling, exploration and planning. One way to represent the terrain given by a set of surface points is to construct a Triangular Irregular Network (TIN).

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2. Photogrammetry

Photography alleviates the time-consuming ground survey effort to a certain extent by allowing the collection of position data for many points in a single image. The science of obtaining such position data from photographs is known as photogrammetry. Ground-based images can be used for photogrammetric measurements, but aerial photography has proven more useful and popular. Unfortunately, aerial surveying is not only expensive and time-consuming, but also produces maps of only relatively small areas of the surface of celestial bodies. For each image produced by aerial photography, several different types of errors must be corrected before the image data can be used to produce a map. Photogrammetry is the "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena"

The traditional, and largest, application of photogrammetry is to extract topographic information (e.g., terrain models) from aerial images. Photogrammetric techniques have also been applied to process satellite images and close-range images in order to acquire topographic or non topographic information of photographed objects. Topographic information includes spot height information, contour lines, and elevation data.

The reason for using Photogrammetry is Raw aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. The photogrammetric modeling based on co-linearity equations eliminates these errors most efficiently, and creates the most reliable ortho images from raw imagery. Photogrammetry is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension elevation.

3. Photogrammetry vs Conventional Geometric Correction

Conventional techniques of geometric correction such as polynomial transformation are based on general functions not directly related to the specific distortion or error sources. They have been successful in the field of remote sensing and Geographic Information Science (GIS) applications, especially when dealing with low resolution and narrow field of view satellite imagery. Introduction to Photogrammetry is necessary because conventional techniques generally process the images one at a time, they cannot provide an integrated solution for multiple images or photographs simultaneously and efficiently. It is very difficult, if not impossible, for conventional techniques to achieve a reasonable accuracy without a great number of Ground Control Points (GCP) when dealing with large scale imagery, images having severe systematic and/or nonsystematic errors, and images covering rough terrain. Misalignment is more likely to occur when mosaicing separately rectified images. This misalignment could result in inaccurate geographic information being collected from the rectified images. Furthermore, it is impossible for a conventional technique to create a 3D stereo model or to extract the elevation information from two overlapping images.

4. Chandrayaan–1: India's First Mission to Moon

Chandrayaan-1, India's first mission to moon, was launched successfully on 22 October 2008 from SDSC SHAR, Sriharikota. The spacecraft was orbiting around the moon at a height of 100 km from the lunar surface for chemical, mineralogical and photo-geologic mapping of the moon. The spacecraft carries 11 scientific instruments built in India, USA, UK, Germany, Sweden and Bulgaria.

Following are the 5 payload developed by Indian scientists:

a. *Terrain Mapping Camera (TMC-ISRO)*
   The aim of TMC is to map topography in both near and far side of the Moon and prepare a 3-dimensional atlas with high spatial and altitude resolution. Such high resolution mapping of complete lunar surface will help us to understand the evolution process and allow detailed study of regions of scientific interests.
b. *Hyper Spectral Imaging Camera (HySI-ISRO)*
   The aim is to obtain spectroscopic data for mineralogical mapping of the lunar surface. The data from this instrument will help in improving the available information on mineral composition of the lunar surface.
c. *Lunar Laser Ranging Instrument (LLRI-ISRO)*
   To provide ranging data for determining accurate altitude of the spacecraft above the lunar surface, determine the global topographical field of the Moon and obtain an improved model for the lunar gravity field.
d. *High Energy X-Ray Spectrometer (HEX-ISRO)*
   The High-Energy X-ray spectrometer covers the hard X-ray region from about 30 keV to about 250 keV. This is the first experiment to carry out spectral studies of planetary surface at hard X-ray energies using good energy resolution detectors.
e. *Moon Impact Probe (MIP-ISRO)*
   The impact probe weighing 29 kg will ride piggyback on the top deck of the main orbiter and will be released at a predetermined time after the orbiter reaches the final 100km orbit to impact at a pre-selected location. In the following sections, TMC payload is dealt in detail.

5. Terrain Mapping Camera

In keeping with the mission objectives, Chandrayaan-1 carries the Terrain Mapping Camera (TMC) designed to map the entire lunar surface during the planned two-year mission. TMC data will enable preparation of a three-dimensional lunar atlas with 5 m sampled spatial and altitude data of 12 bit digitization. The TMC will image in the panchromatic spectral band of 0.5 – 0.75 µm with a stereo view in the fore, nadir and aft directions of the spacecraft movement and have a base to height ratio of one. The Terrain Mapping Camera (TMC) on India's first satellite for lunar exploration, Chandrayaan-1, is intended for systematic topographic mapping of the entire lunar surface, including the far side and the polar regions. The aim is to prepare a three-dimensional atlas of the moon with high spatial and altitude sampling for scientific studies. The 5 m sampling of the camera is chosen to be commensurate with 1 : 50,000 scale mapping and desirable contour interval of less than 10 m for height information. Such high resolution imagery of the entire moon will help detailed study of specific lunar regions of scientific interests and further our understanding of lunar evolution. For obtaining the elevation information the camera will have along-track stereo viewing, acquiring stereo triplet of the target scene in the fore, nadir and aft views, as the spacecraft moves in a 100 km circular polar orbit.

a. *Scientific objective*

The aim of TMC is to map topography of both near and far side of the moon and prepare a 3-dimensional atlas with high spatial and elevation resolution of 5 m. Such high resolution mapping of complete lunar surface will help to understand the evolution processes and allow detailed study of regions of scientific interests. The digital elevation model available from TMC would improve upon the existing knowledge of Lunar Topography.

TMC will measure the solar radiation reflected / scattered from moon's surface. TMC uses Linear Active Pixel Sensor (APS) detector with in-built digitizer. Three cameras are used in the pay load because it will be leading to a 3 dimensional atlas of the model. The images taken from 3 cameras which are placed at different angles will help us in knowing the depth of the crater or the height of the peak.

Figure 1 Terrain mapping camera

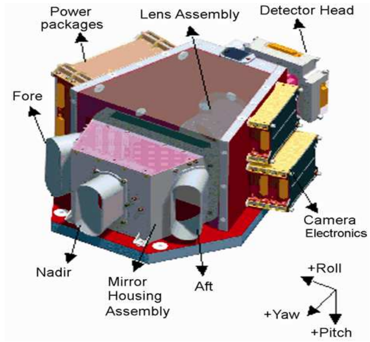

Figure 2 Viewing Geometry of the Terrain Mapping Camera

The most important reason why we use Digital Elevation Model (DEM) is because available data sources do not approximate terrain (distribution, density, accuracy, etc. of the sources is not appropriate) and also perception or interpretation of earth's surface is not the same when more DEM operators work on the same problem; operator's own imagination is common and reasonable problem in DEM production.

For obtaining the elevation information the camera will have along-track stereo viewing, acquiring stereo triplet of the target scene in the fore, nadir and AFT views as the spacecraft moves in 100 km circular polar orbit. With this arrangement the entire lunar surface can be imagined without occlusion with at least one stereo pair. The base to the height ratio (B / H) of the camera is 1.0 For the 100 km polar orbit, the equatorial shift of the moon between two orbits is about 32.62 km. The swath of the instrument is 20 km.

b. *Details of the Instrument*

The subsystems of the TMC instrument are optical assembly, detector assembly, electronics, and mechanical system. The TMC is highly compact, low weight, low power dissipating instrument. The stereo data is collected by the triplet imaging in the along-track direction with three-linear detectors.

Optical subsystem: the optical configuration for the TMC comprises a single multi-element f / 4 lens assembly required along track field angle of ± 25 0 achieved with the help of a pair of plane mirrors placed strategically on either side.

c. *Detector Subsystem*

The TMC detector head is built around monolithic complementary Metal-oxide –semiconductor (CMOS) linear array active pixel sensor (APS). The APS has integrated sensing elements, timing circuitry, video processing and 12-bit analog to digital conversion. Three detectors are kept in the focal plane for the fore, nadir and aft views.

d. Electronics Subsystems
The electronics for the instrument is designed to meet the detector and system requirements. It is modular and separate for the three detectors. The electronics is miniaturized and low power dissipating.

e. Mechanical Subsystem
The mechanical subsystem consists of the structure and the electronic packaging. The main consideration is to meet the system performance by providing the stability for the static, dynamic and thermal load conditions with minimum weight and size.

6. Applications

Digital topographic data sets facilitate urban planning and enable engineers to model new roads within an existing landscape. Linear constructions like roads, railway tracks, oil and gas pipelines, bridges and electric power lines may be planned without having to send surveyors onsite.

Hydrological situation is important for the agricultural activities like irrigation management and for power. Companies when estimating the market of electricity. Insurance companies are very interested customers of this kind of manipulated DEM data for a client oriented assessment of flood risks.

Exploration experts are possibly the most experienced users of remote sensing data and digital elevation models. By analyzing optical radar images they determine promising regions of potential mineral deposits around the world. A combination of remote sensing data, especially DEMs, with gravity maps the identification of oil spills on satellite imagery and other phenomena and combinations leads the prospecting companies to successful explorations.

Disaster management is often impeded by lacking, incorrect or simply imprecise information about the situation on the ground. Up-to-date and precise data are imperative in assessing potential risks (posed by floods, for example), in employing relief personnel effectively, in disaster aid (e.g., locating adequate spots for dropping of relief supplies) and in analyzing damages and changes

7. Conclusion

Digital elevation models may be prepared in a number of ways, but they are frequently obtained by remote sensing rather than direct survey. Digital elevation model (DEM) is one of the most important datasets for the greater part of spatial-based studies and research. A high quality DEM could be generally used as all-purpose dataset, but unfortunately its production could be very expensive. If a nature of application is known that applies DEM and if our demands for the final result are clear, then the DEM selection is adjusted or its production can be simplified.

Generation or selection of a DEM suitable for different spatial analyses or visualization purposes is being discussed here. At the first it is stressed that DEM is only a model that is approximation of the nature and its nominal ground. The models, in the instant case DEMs, might be different concerning their purpose of use, quality of data sources or interpolation algorithms, experiences of operator, etc. The starting point is that the DEM should be carefully produced or chosen regarding purpose of our applications.

References

[1] C. Y. Lee ,S. D. Jones, C. J. Bellman, " *Dem creation of a snow covered surface Using digital aerial photography*", Buxton School of Mathematical and Geospatial Sciences, RMIT University, GPO Box 2476V, Melbourne 3001, Australia

[2]. Hiroyuki HASEGAWA, Kaoru MATSUO, Mamoru Koarai, Nobuyuki Watanabe, Hiroshi Masaharu, and Yoshikazu, Fukushima "*Dem Accuracy And The Base To Height (B/H) Ratio Of Stereo Images*", Geographic Information Analysis Research Division, Geographical Survey Institute, Japan

[3]. B. Gopala Krishna, Amitabh, Sanjay Singh, P. K. Srivastava and A. S. and Kiran Kumar, "*Digital Elevation Models of the Lunar Surface from Chandrayaan-1 Terrain Mapping Camera (Tmc) Imagery – Initial Results*", Signal and Image Processing Area, Space Applications Centre, Ahmedabad-380015.

[4]. A. De Wulf, M. Hennau and D. Constales TIN-Based Digital Terrain Modeling Using Multibeam Data

[5]. D. P. Rao "*Geographic data needed in the interpretation of Indian satellite-based remote sensing data:Opportunities and realities Department of Space*", National Remote Sensing Agency, Balanagar, Hyderabad 500 037, India.

[6]. S.Suganthi , K.Srinivasan , "*Digital Elevation Model Generation And Its Application In Landslide Studies Using Cartosat1*" M.E Geo Informatics, IRS, Anna University, Institute of Remote Sensing Anna University, Chennai

[7]. R.L. Kirk, B.A. Archinal, L.R., Gaddis, and M.R. Rosiek "*cartography for lunar exploration: 2008 status and mission plans*".