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Technological advancements in topographical survey- Utility of Digital Elevation Models and GIS

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Abstract

For infrastructure projects, located in highly rugged inaccessible Himalayan terrain, feasibility to carry out conventional topographical surveys is very limited. In such areas, Digital Elevation Model (DEM) plays vital role in representing topography using the raster data model. DEMs can be generated from various sources such as field measurements/surveys or from existing topographic maps, from aerial/satellite stereo data using photogrammetric methods, from SAR (Synthetic Aperture Radar) data using interferometric techniques or from LIDAR surveys. Many of these complete global coverage data are freely available for users on open platforms of USGS and NASA Earth-Data, NRSC, etc. Now a days SAR based DEMs such as SRTM, ASTER and ALOS PALSAR are very useful for generation of contours with adequate precision. These RADAR based data are more accurate as compared as compared to DEMs generated through photogrammetric Remote Sensing because very less human intervention in preparation of DEMs and it reduces the effect of vegetation cover considerably.
The present study highlightsthe effective applications of DEMs through case study examples correlating contours developed based on DEMs with Ground Control Points (GCPs). Using this DEM as input in state-of-the-art Geographical Information System software QGIS, contours have been generated for two different regions, viz., Khardung Laarea in Laddakh, India and Trongsa Dzong area in Central Bhutan.
DEM based contours and the ground topographical maps were perfectly matched in horizontal coordinates and a good match has been observed in elevation ranging from 1.7m to 6.8m. It has been found that, for the study areas, under horizontal near even ground conditions, the delineated elevation lies within the error limits of 1-2m, however, under steep topographical conditions, the error level increased to about 6.7m. The study revealed that DEMs and GIS have immense application in planning and management of infrastructure projects in fast and cost effective manner.

Keyword : Digital Elevation Model, SAR, QGIS, Contours, GCPs.

1. Introduction:

Digital Elevation Models (DEMs) provides representation of Earth surface with latitude, longitude and altitude in the form of three dimensional models. Digital Elevation Model is a quantitative representation of terrain and is consequential for geological and hydrological applications. Generally, DEM of an area is studied using the elevation data, which in turn, is obtained through various sources such as from existing topographic maps, from aerial/satellite stereo data using photogrammetric methods, from SAR (Synthetic Aperture Radar) data using interferometric techniques or from LIDAR surveys. Most DEMs are geoid-based and require a baseline correction before they can be used for terrain extraction and contour preparation.
This paper presents the attempt undertaken for correlation of DEM based contour maps with the actual ground contours for two project areas located at Khardung La area of Leh District, Ladakh, India and Trongsa Dzong area in Central Bhutan. The study had shown that the DEMs have immense application in planning and management of infrastructure projects in fast and cost effective manner.

2. Digital Elevation Model (DEM):

DEM is frequently used to refer to any digital representation of a topographic surface and is the simplest form of digital representation of topography. DEMs are used to determine terrain attributes such as elevation, slope and aspect at any location. Most DEMs are geoid-based and require a baseline correction before they can be used for terrain extraction and contour preparation (*Gurugnanam B., 2014)*. The quality of DEM is based on accuracy of elevation at each pixel and it depend on various factor like terrain roughness, resolution etc. Three Digital Elevation Models (DEMs) were compared for assessment of their suitability for the study.

SRTM -Shuttle Radar Topographic Mission (SRTM) digital elevation data offer worldwide coverage of void filled data at a resolution of 1 arc-second (30 meters) and provide open distribution of this high-resolution global data set. The SRTM mission used single-pass interferometry, which acquired two signals at the same time by using two different radar antennas (*Mukul M. et. al., 2015*). An antenna located on board the space shuttle collected one data set and the other data set was collected by an antenna located at the end of a 60-meter mast that extended from the shuttle "Endeavour".

ALOS PALSAR - Advanced Land Observation Satellite - Phased Array type L-band Synthetic Aperture Radar (ALOS-PALSAR) had L-band Synthetic aperture radar (SAR) yielded detailed, all-weather, day-and-night observation, as well as repeat-pass interferometry. ALOS-PALSAR was a mission of the Japan Aerospace Exploration Agency (JAXA). The pixel resolution of Digital Elevation Model is 12.5m.

ASTER DEM:ASTER is an imaging instrument built by METI and operates on the NASA Terra platform. Images are acquired in 14 spectral bands using three separate telescopes and sensor systems. ASTER DEM standard data products are produced with 30m pixel resolution. These DEMs are geo-referenced and ortho-rectified data in UTM or Geographic coordinate system and hence, accuracy lies within meter in horizontal directions.

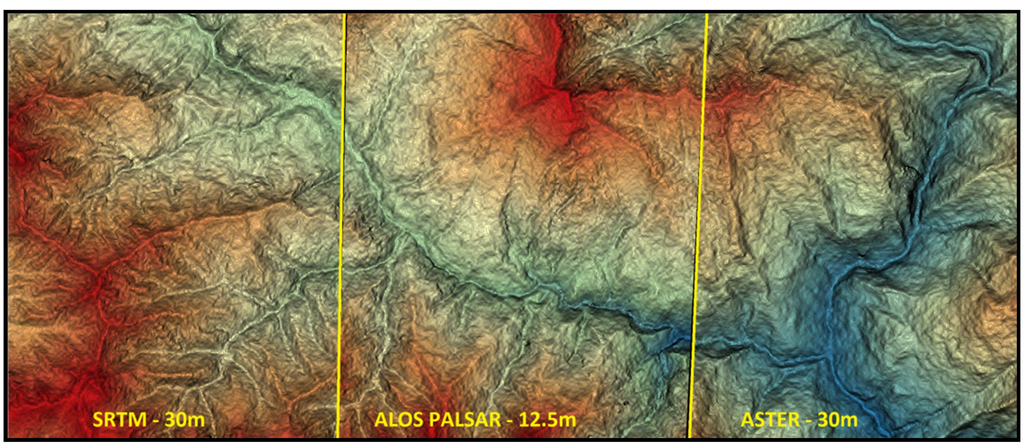

Figure1: Digital Elevation Models (SRTM, ALOS PALSAR& SRTM)

These are used world-wide for scientific works within the accuracy range from 2m to 15m in elevations depending on terrain conditions. In flat terrain accuracy level is more in comparison with undulated hilly topographical conditions.

Volume XLIV, Nos. 1 & 2
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3. Software Utilized for the Study:

During the case study, Image registration, reprojection (if required), subset formation, radiometric resolution and contour generation has been done by utilizing state-of-the-art satellite data processing software QGIS. QGIS is an open source geographic information system (GIS) software, allowing users to analyze and edit spatial information in raster as well as vector forms.

QGISsupports shapefiles, coverages, personal geodatabases, dxf, MapInfo, PostGIS, and other formats. It also has capabilities to integrate with other open-source GIS packages, including PostGIS, GRASS GIS, and Map-Server.It has also been used for correlating with GCPs and preparation of interactive DEM and contour maps. In comparison to conventional Remote Sensing package ERDAS Imagine, QGIS provides sharp Digital Elevation Models and generate contours in interactive ways. These contours can also be exported in terms of AutoCAD drawing files for further correlation with topographic map.

4. Case Studies:

The study presents two case studies related to areas located in highly undulating terrain. The technique applied successfully in these areas and correlated well with the topographical data collected during ground surveys. The details are given hereunder:

i. ***Khardung La Area, Leh District, Laddakh, India –*** The proposed study is taken up for Khardung La area of Leh District Ladakh, India. The study area lies between $34^0$15' & $34^0$20' north Lattitude and $77^0$30' & $77^0$40' east Longitude covering an area of about 170sq Kms (Fig.2). Physiographically; it is a hilly region with an altitude ranging from 4280M to 5750M m. Slope of this region varies from gentle to very steep.Geologically, the granitoids and associated rocks of Ladakh batholith are well exposed in the area. For the study, ALOS PALSAR data has better pixel resolution of 12.5m in comparison to 30m pixel resolution of SRTM data and ASTER data. Hence, ALOS PALSAR DEM data has been used for generation of contour. Based on the Elevation values of GCPs, aunified baseline correction of +30m has been applied to the dataset and contour map has been prepared. The state-of-the-art GIS software QGIS has been utilized for contour generation. These developed contour maps then corrected using Ground Control Points and correlated with the available ground topographical survey data.In general, the topography in the area varies from EL4600M to EL5550M. The details are given in Table-1.

Figure 2: Location of the Khardung La, Ladakh

Table-1
Correlation of Elevation with GCPs for Khardung La area, Ladakh.

GCP	Location & Elevation	DEM Elevation	Difference	
			Elevation	Horizontal
K-1	E739374.396,N3797590.115,EL5249.8M	EL 5245M	4.8m	Negligible
K-2	E739781.065,N3796120.407,EL5361.0M	EL 5365M	4.0m	Negligible
K-3	E741365.426,N3794034.551,EL4788.3M	EL 4790M	1.7m	Negligible

The DEM based contour map has been superimposed on the topographical map developed. A good match has been observed between the two maps of different origins.

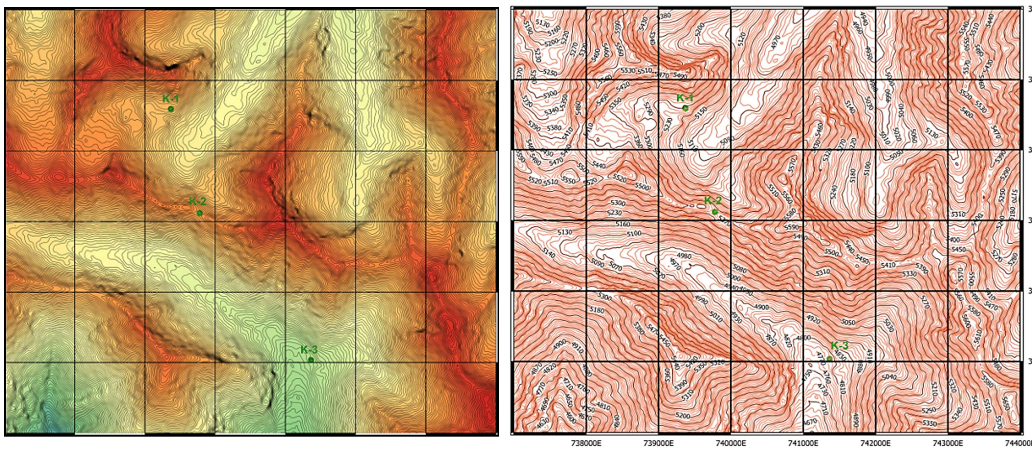

Figure 3: DEM and developed Contour Map of KhardungLa area, Ladakh

After baseline correction, All the GCPs are correlated well with the topographical data within 5m accuracy. This precession has been achieved because of low vegetation cover.

ii. ***Trongsa Dzong, Bhutan*** **–**The study area is located in Trongsa Dzong (District) in Central Bhutan. Geologically, the area lies within the Thimpu Formation of Central gneissic complex with magmatites and biotite granite gneiss having thin bands of quartzite mica schist and talc silicate rocks.

For the study, SRTM, ASTER & ALOS PALSAR were compared and it has been found that SRTM data is more consistences from other DEMs. Hence, SRTM DEM data has been used for generation of contour map.No baseline correction was needed as the elevation values are in agreement with the Ground Control Points. The general topography of the area varies from EL1000M to EL3500M.The detailed review is given in Table-2.

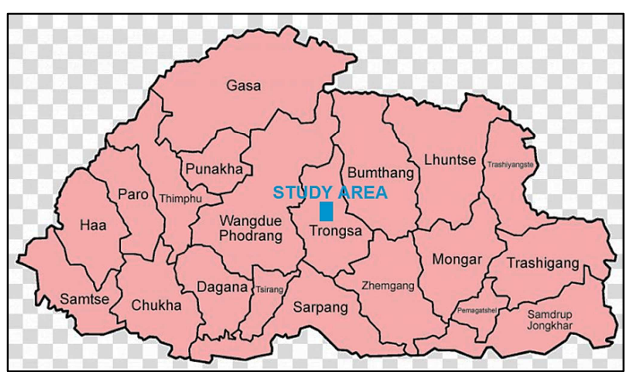

Figure 4: Location of Study Area, Trongsa, Bhutan

Table-2
Correlation of Elevation with GCPs for Trongsa Dzong area, Bhutan.

GCP	Location & Elevation	DEM Elevation	Difference	
			Elevation	Horizontal
M-1	E252777.066,N3042712.926,EL2098.3M	EL 2092M	6.4m	Negligible
M-2	E253070.453,N3035074.645,EL1785.2M	EL 1790M	4.8m	Negligible
M-3	E252968.235,N3034711.813,EL1586.1M	EL 1590M	3.9m	Negligible
M-4	E257827.583,N3029194.611,EL1071.9M	EL 1075M	3.9m	Negligible

The DEM based contour map has been superimposed on the topographical map developed. A match has been observed between the two maps at many points, however, at places, due to steep topography, the differences in elevations are observed up to the range of 10m.

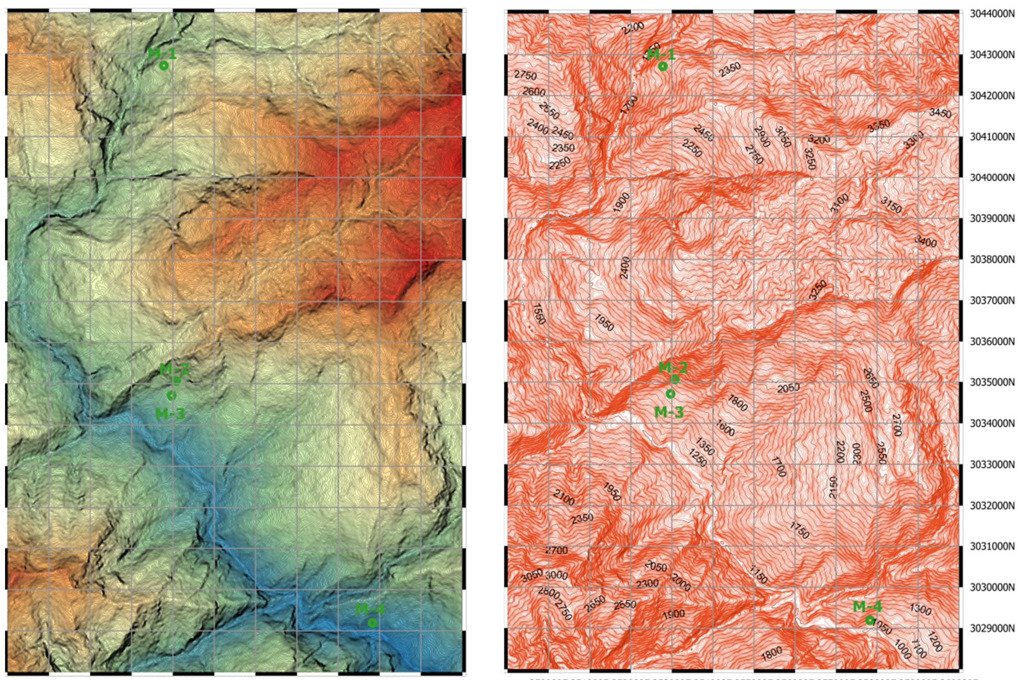

Figure 5:DEM and developed Contour Map of the study area, Trongsa Dzong area, Bhutan

All the GCPs are correlated well with the topographical data within 10m accuracy. This precession has been achieved in spite of thick vegetation cover and steep topographical conditions observed at places.

5. Conclusions:

The study has been conducted in order to validate the accuracy of the topographical contours developed through Digital Elevation Model by comparing with the actual field topographical survey. The GIS software QGIS has been utilized for processing of the DEM data and preparation of contour maps. These contour maps have been correlated with actual ground topographical data utilizing AutoCAD software. Based on the observations, following conclusions are made towards integration of these data and scope of improvements:

- Satellite data based Digital Elevation Model (DEMs) can be utilized effectively along with topographical survey data for uncovered and inaccessible areas. Ground Control Points plays vital role in baseline correction of DEMs in order to get more precision in the developed contours. It is also suggested that for better correlation, topographical data needs to be collected in UTM/Geographic coordinate system.
- As per observations of present study, the DEM based contours and the ground topographical maps were perfectly matched in horizontal coordinates and a good match has been observed in elevation ranging from 1.7m to 6.8m. It has been found that, for horizontal near even ground conditions, the delineated elevation lies within the error limits of 1-2m, however, under steep topographical conditions, the error level increased to about 6 -7m.
- As these DEM based maps are developed in very fast and economic way and has good horizontal spatial accuracy, it is suggested that the initial geological field surveys can be undertaken with reference to these DEM based contour maps. After availability of topographical survey of the area, same can be transferred on topographical maps.
- QGIS is an open source Geographic Information System (GIS) software, allowing users to analyze and edit spatial information in raster as well as vector forms. It provides sharp Digital Elevation Models and generates contours in interactive ways. These contours can also be exported in terms of AutoCAD drawing files for further correlation with topographic map.
- At many places, it is not possible to carry out topographical surveys such as inaccessible areas of HRT, big reservoir area, etc. Under such conditions these DEM based contour maps canprovide vary valuable information about these inaccessible reaches. DEMs are available at global coverage and can be used for processing and developing contours for any region utilizing QGIS software package within a very short time and most importantly with minimum expenditure.

Hence, Satellite based Digital Elevation Models provide quick and efficient analysis of the large areas in a very fast and economic way. Adoption of these technological advancements are today's need for preliminary investigations of infrastructure projects in initial stages of their development.

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