Journal of Geomatics Vol 11 No. 2 October 2017

Generation and analysis of Digital Elevation Model (DEM) using Worldview-2 stereo-pair images of Gurgaon district: A geospatial approach

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(Received: Jun 18, 2017; in final form: Sep 20, 2017)

Abstract: The use of very high resolution satellite images in photogrammetric tasks is increasing continuously, especially in tasks such as Digital Elevation Models (DEM) generation or ortho-images production. A large number of new photogrammetric uses of Earth Observation data appear due to improvement of the geometric accuracy of the products. Elevation data can be represented as raster DEM (a grid of squares or rectangles) or as a triangular irregular network or as contours. The present study focuses on the generation of DEM and contours of the study area using Worldview-2 stereo pair imagery (with spatial resolution of 0.5 meter). The contours are generated at 5 meter vertical interval. The methods applied in this study are a linear polynomial correction using 3-Dimensional ground control points (GCPs), rational polynomial coefficient (RPC) correction without refinement and RPC correction with linear refinement using 3D GCPs. The GCPs were collected by means of differential global positioning system (D-GPS-Survey). Investigation of the results is performed by examining the RMS error of DGPS check points and RMS error for RPC model.

Keywords: Ortho rectification, D-GPS, RPC, RMS error

1. Introduction

A Digital Elevation Model (DEM) is a representation of altitude of Earth surface with latitude and longitude i.e. X, Y horizontal coordinates and height Z (Pandey and Venkataraman, 2012) and is also widely known as a digital terrain model. The digital terrain model provides a so-called bare-earth model, devoid of landscape features and it is often required for flood or drainage modelling, land-use studies, geological applications and many more. A DEM can be represented as a raster (a grid of squares or rectangles, also known as a height map when representing elevation) or as a vector-based triangular irregular network (TIN). The TIN dataset is also referred to as a primary (measured) DEM, whereas raster DEM is referred to as a secondary (computed through interpolation) DEM (Maune 2007). The DEM could be acquired through techniques such as photogrammetry, LIDAR, land surveying, etc.

The Digital Globe's WorldView-2 satellite was launched in October 8, 2009 and has the ability to collect panchromatic and multispectral images (in 8 bands) with pixel size of 0.46 m and 1.84 m at nadir, respectively. WorldView-2 imagery products are delivered with a set of metadata files called Image Support Data (ISD). The proposed orientation model is applied only to Basic Imagery product, which includes Attitude, Ephemeris and Geometric calibration files.

2. Objective

The objectives of this study are as follows:
1- To generate Digital Elevation Model and contours with 5 meter vertical interval of the study area.
2- To improving the horizontal as well as vertical positioning accuracy.
3- To perform analysis of the terrain.

3. Study area

Gurgaon District lies between 27º 39´ 17" and 28º 32´ 25" North latitude, and 76º 39 ´ 30" and 77º 20ˑ 45" East longitudes. On its north district is bounded by the Rohtak and Delhi. Faridabad lies to its east. On its south district shares its boundaries with Uttar Pradesh and Rajasthan. In the west, this district is bounded by Rewari district and Rajasthan. Location map of the study area is given in figure 1.

4. Data and methodology

The main technical characteristics of WorldView-2 sensor, with a focal length of 13246.139 mm (Deltsidis and Ioannidis, 2011) and stereo capacity with Agile Telescope, are given in table 1.

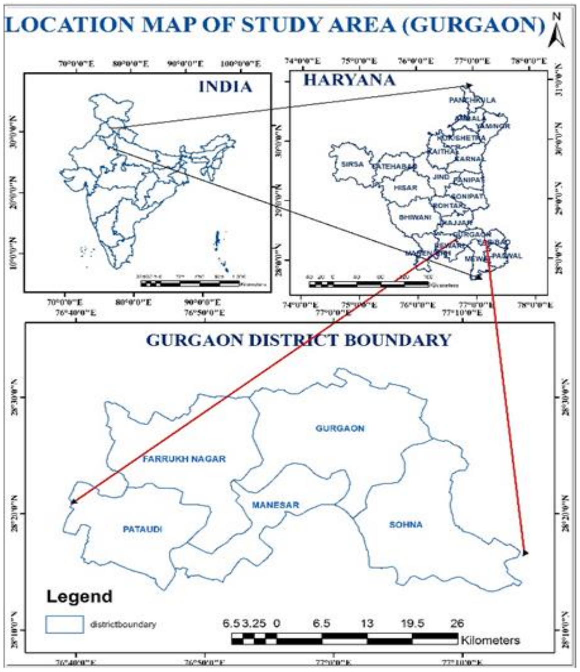

Figure 1: Location map of the study area

Table 1: Description of satellite data

S.N.	Parameter	Description
1	Satellite	World View-2
2	Date of Acquisition	May 2011 to June 2012
3	Satellite Altitude	770 km
4	Orbit	Sun synchronous
5	Spectral Resolution	450 - 800 nm
6	Spatial Resolution	0.46 m GSD at nadir, 0.52 m GSD at 20° off-nadir
7	Radiometric Resolution	11 bits
8	Swath Width	16.4 km
9	view angle	Less than 25^0

Source: Digital Globe and supporting file provided with satellite images

There are many methodologies and techniques to generate DEM but in this study DEM and contours are extracted using stereo pair of satellite image with DGPS point. A specific methodology and technique developed for the same is as follows.

Digital stereo data of World View-2 was acquired through National Remote Sensing Centre, Hyderabad having spatial resolution of 0.5 m for this study with off nadir angle less than 20 degrees. After acquiring satellite data, it was checked for the percentage of clouds, haze, restricted area and gaps in area of interest. After acquiring satellite data it is mosaic according strip or scene because only first tile has RPC file *(*Rational Polynomial Coefficient*)* which is a sensor model commonly used by the remote sensing industry to determine the ground coordinates of pixels in high resolution satellite imagery.

Single block for the whole study area was created with projection parameters as UTM projection, Spheroid WGS 84, Datum WGS 84 and 43N UTM zone. Very high resolution stereo satellite imagery (world view-2) along with the RPC files was input to the AT (Areal Triangulation) block. After that, pyramid layer was generated for all image of the block and attached with RPC file. Tie point generation and block triangulation was carried out by refinement of image geometry model (RPC) supplied with the imagery and ground control point which are generated by DGPS survey of the study area. The objective of block triangulation is to determine the position and orientation of each image in a mapping frame which are known as exterior orientation (EO) parameters. Digital terrain model was extract of individual images of the block in LTF (Leica Terrain File) file format which is export into ERDAS Imagine (.img) format. Digital terrain model (DTM) extraction can be performed after complete setup of the block file (User Guide Erdas 2011). After that with the input as DEM the contour line with 5 meter vertical interval are generated for whole study area. Projection for output DEM images was also define as whole block. The methodology adopted for the present work is systematically presented in figure 2.

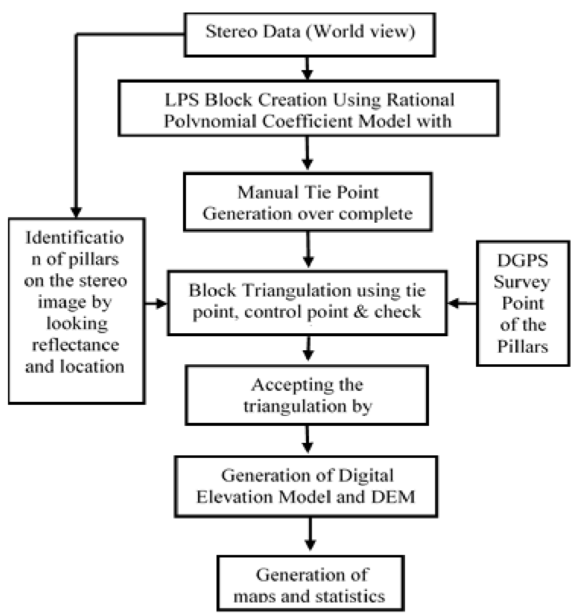

Figure 2: Flow chart of the methodology

5. Results

The evaluation of the DEM produced by the fore mentioned methodology was made by calculating the RMS error, based on eighteen reference DGPS points, the coordinates of which are known with high accuracy. The RMS error is expressed as distance (m) in the source coordinate system.
RMS error is calculated with a distance equation:

$$\text{RMS Error} = \sqrt{(x_b - x_g)^2 + (y_b - y_g)^2 + (z_b - z_g)^2}$$

where:
X_b, Y_b, Z_b are the input source coordinates or image coordinates
X_g, Y_g and Z_g are the retransformed coordinates

Comparison between GCPs and block coordinates is given in table 2 whereas table 3 provides performance Of the checkpoints. The calculated RMSE for whole block is 0.423 whereas for check point it is 0.95 m.

There are many applications of DEM as determining attributes of terrain such as drainage basins and watersheds, modelling of hydrologic functions. In the current study, the terrain elevation values are used to prepare DEM. The DEM map is shown in figure 3. The elevation of the study area varies from 192 m to 329 m. From Figure 3, it can be seen that the south and southern eastern part of the study has high elevation, while south-east has lowest elevation.

Slope is defined by a plane tangent to a topographic surface, as modelled by the DEM at a point. The DEM data were given as in input for the preparation of Slope map.

Table 2: Comparison between GCPs and block coordinates

Points	**Ground control Point**			**Block coordinate**			**Difference in Coordinates**		
	X_g(m)	Y_g(m)	Z_g(m)	X_b(m)	Y_b(m)	Z_b(m)	X(m)	Y(m)	Z(m)
1	666359.85	3153004.97	214.63	666359.19	3153005.2	215.47	0.66	-0.23	-0.83
2	651761.44	3152163.47	216.76	651761.25	3152163.6	216.39	0.18	-0.17	0.36
3	663565.06	3140809.87	225.13	663561.73	3140810.7	226.04	3.33	-0.78	-0.91
4	662056.12	3132178.44	228.53	662056.25	3132179.4	228.52	-0.12	-0.93	0.01
5	664801.34	3127112.02	234.32	664801.9	3127112.3	234.65	-0.55	-0.24	-0.32
6	650451.16	3127214.52	240.05	650451.51	3127214	240.94	-0.35	0.53	-0.89
7	681196.01	3125158.03	251.5	681196.25	3125158.3	250.15	-0.23	-0.24	1.34
8	684588.01	3126884.45	246.68	684588.26	3126884.4	245.03	-0.24	0.03	1.64
9	697277.58	3131882.89	325.26	697277.51	3131883.1	324.83	0.07	-0.21	0.42
10	703829.87	3124256.09	198.36	703829.62	3124256.2	197.88	0.25	-0.07	0.48
13	720777.05	3129370.44	194.9	720777.93	3129370.5	193.54	-0.87	-0.06	1.36
14	710173.65	3147184.69	254.71	710173.04	3147184.3	253.2	0.6	0.42	1.5
15	713748.34	3144283.31	299.79	713748.83	3144284	299.09	-0.48	-0.66	0.69
16	697354.95	3158813.79	212.48	697354.06	3158814.6	212.18	0.88	-0.8	0.3
17	684859.63	3155337.6	211.31	684859.48	3155337.6	211.71	0.15	0.02	-0.39
18	680115.4	3154665.31	214.23	680115.21	3154665.3	214.35	0.19	0.04	-0.12
						RMSE	0.21	-0.21	0.29

Table 3: Check point performance

S.N.	Check Point(m)			Block Coordinate(m)			Difference in Coordinates(m)		
	X	Y	Z	X	Y	Z	X	Y	Z
1	679580.91	3147811.12	216.99	679581.21	3147811.91	215.97	0.3	0.79	-0.2
2	698638.25	3148543.59	222.45	698638.88	3148544.03	221.63	0.63	0.45	-0.82
3	702752.43	3126375.01	206.11	702753.37	3126375.88	205.11	0.94	0.87	-0.79
4	660279.14	3146027.83	219.92	660279.92	3146026.98	221.8	0.78	-0.85	0.88
5	724566.96	3125671.36	193.24	724567.57	3125672.08	193.25	0.62	0.72	0.01

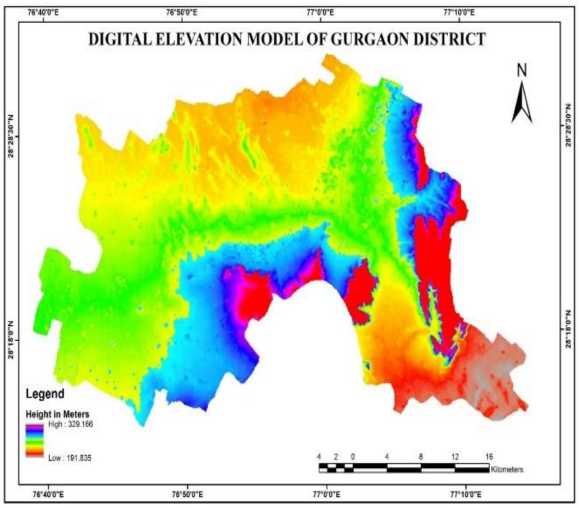

Figure 3: Digital Elevation Map (DEM) of the study area

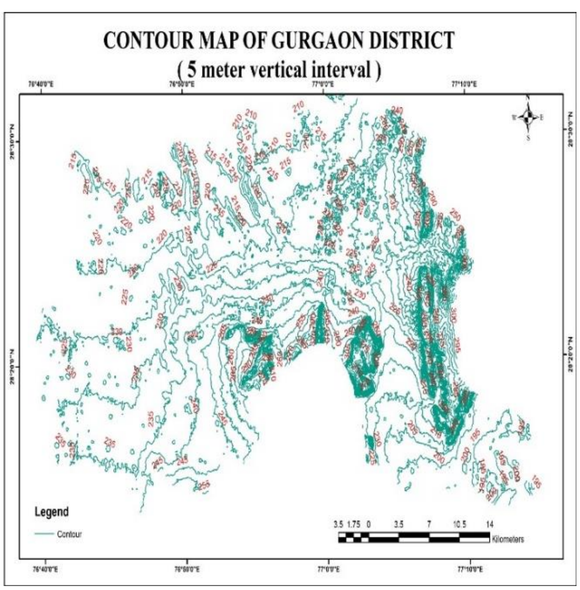

Figure 4: Contour map of study area

Table 4: Area cover under each slope category

S. N.	Slope in Degree	Area Cover (Percentage)
1.	0-5	96.12
2.	5-10	2.20
3.	10-15	0.95
4.	15-20	0.49
5.	20-25	0.23

The slope map is given in figure 5. In south eastern side, there is steep slope. Very gentle slopes are confined to the western and northern part. Table 4 shows the area covered by each slope category. Aspect is the directional measure of slope, measured in degrees and it ranges from 0 degree at the North, moves clock wise and ends with 360 degrees at the North.

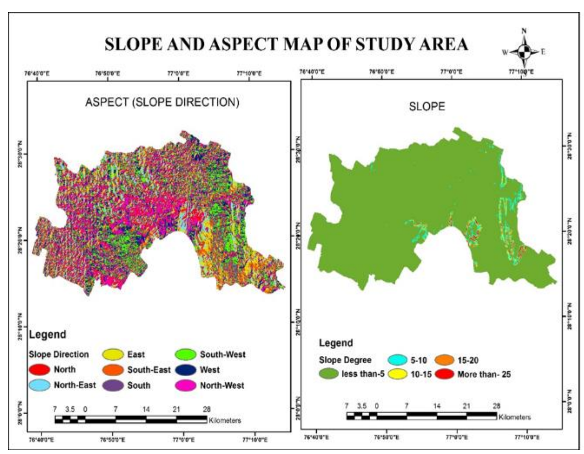

Figure 5: Slope and aspect map of study area

Aspect can have large influence on temperature. The aspect of a slope can make very significant influences on its local climate. For example, because the Sun's rays are in the west at the hottest time of day in the afternoon, in most cases a west-facing slope will be warmer than a sheltered east-facing slope

In the study, DEM data and slope values are used to generate the Aspect map. Figure 5 map is showing slope direction and area cover by each direction is shown in table 5.

Table 5: Area cover under each direction

S. N.	Aspect	Area Cover (Percentage)
1.	North	14.97
2.	North-East	12.40
3.	East	10.10
4.	South-East	7.95
5.	South	8.24
6.	South-West	12.95
7.	West	16.88
8.	North-West	16.50

Conclusion

In the present study, a DEM was generated using a geospatial approach for Worldview-2 stereo-pair images. The calculated RMSE for whole block was 0.423 m whereas for check points was 0.95 m, which can be considered as acceptable. The raster DEM was used to produce slope, aspect and contour maps. Such maps are required for several applications of geo-informatics.

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