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Research Paper

Accuracy Assessment of Generated DEMs and Ortho-images from GeoEye-1 Stereo pair for a selected Hilly Area of Bangladesh

Science

KEYWORDS : GeoEye-1 image, DEM, Ortho-image, Bangladesh.

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ABSTRACT

In the current study, the accuracy of DEM generated with and without GCPs from high resolution GeoEye-1 satellite images for a selected area in southeastern hilly areas of Bangladesh. An area covering 130 km2 in the clipped part of panchromatic GeoEye-1 stereo imagery with resolution of 0.5m was collected for the study. It was found that when no GCPs were used in the RPC model, the CP RMS vertical error was approximately 6m and the errors reduced to 1.25m when GCPs are used. The planimetric shift in X and Y directions between the generated ortho-images with and without GCPs has also been investigated. The study shows that the improvements in locational positioning in X and Y after using GCPs has occurred through the shifting by 2.67m and 1.21m respectively as indicated by the respective RMS values.

1. Introduction

A Digital Elevation Model (DEM) is digital data in which each point represents latitude, longitude and height. Extraction of accurate DEMs is important for map generation, three-dimensional GIS, development planning, environmental monitoring and so on. Among many possible sources that can be used for DEM generation, satellite images have potentially several advantages [1].

The geometric quality of an ortho-imagery depends on the accuracy of the orientation during Epipolar generation, accuracy of ground control points and geometric quality and resolution of the used DEM. All the accuracy of the derived terrain parameters like slope, aspect, drainage, watershed boundary, cut and fill calculations etc. in terms of the position, geometry and orientation, depends on the accuracy of the DEM used to generate or extract these parameters [2]. As one of the world's highest resolution commercial Earth-imaging satellites, GeoEye-1 has exhibited unsurpassed georeferencing accuracy [3, 4]. Fraser and Ravanbakhsh [3] achieved vertical and horizontal accuracies of 0.25 m and 0.10 m, respectively, using a stereo-pair of GeoEye-1, whereas Mitchell and MacNabb [5]), working again onto a GeoEye-1 stereo-pair, reported a vertical Root Mean Square Error (RMSEz) of 0.25 m by using a lidar-derived DEM comprising an area close to 50 km2 as ground truth.

The present study deals with the generation of DEM using VHR GeoEye-1 stereo image with and without GCPs and assessment of the accuracy of position (X,Y and Z) with respect to the GSP survey data. The horizontal shift of the ortho-images with and without GCPs has also been studied.

2.1 Study Area

The study area lies within 91^0 56' 13.92" E/ 22^0 06' 10.44" N/ and 91^0 02' 06.54" E/ 21^0 58' 31.86" N geographic co-ordinates, which covers a total area of 130 km^2 approx. (Fig. 1). The area is situated under three administrative units of chittagong district namely, Banshkhali, Lohagara and Satkania Upazila (sub-districts). The area homestead area, a small number of water bodies and mainly hilly region of having ground height from 3m to115m from Mean Sea Level (MSL). The dark crosses indicate the 9 points where the planimetric readings were taken for estimating the ortho-image shifts.

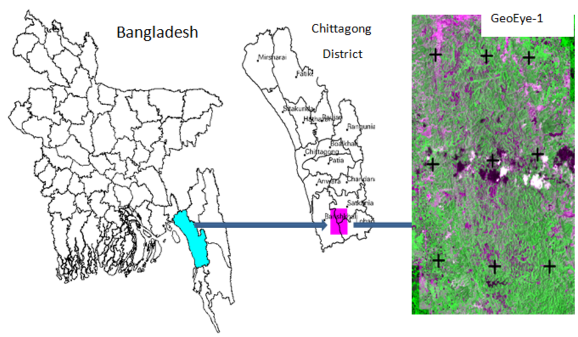

Figure-1: Study area with the GeoEye-1 image.

2.2 GeoEye-1 Stereo Data

A clipped part of 130 km^2 area from GeoEye-1 stereo PAN band with standard geometrically corrected processing level was imported for the study. The image scene was captured on 11 April 2012. The imagery has been ingested in a sensor camera model along with corresponding rational polynomial coefficients (RPCs). The imaging geometry is shown in table-1.

Table-1: Parameters characterizing the GeoEye-1 image

Image Product	Fore scene	Aft scene
Collection Azimuth	4.63º	210.93º
Collection Elevation	62.78º	77.74º
Sun Angle Azimuth	121.76º	122.16º
Sun Angle Elevation	66.26º	66.47º
Product Pixel Size	0.5m	0.5m
Cloud Cover (%)	2	2

2.3 Field Survey

The field data collection was performed using single frequency ProMark3 RTK to take positional measurements used as ground control points (GCPs) and check points. GPS was set with geographic projection and WGS84 datum. According to Aschenbach [6], the computed accuracy of single unit-single frequency PM3 GPS is to a meter or less and doubles in horizontal and vertical directions respectively.

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3. Methodology

The methodological steps for the study using Leica Photogrammetry Suite (LPS) software are shows in Figure-2. A block project file has been created inside the software defining the geometric model as RPC. The GeoEye-1 stereo-pair was added and the block was assigned in the horizontal and vertical coordinates with geographic projection and WGS 84 datum.

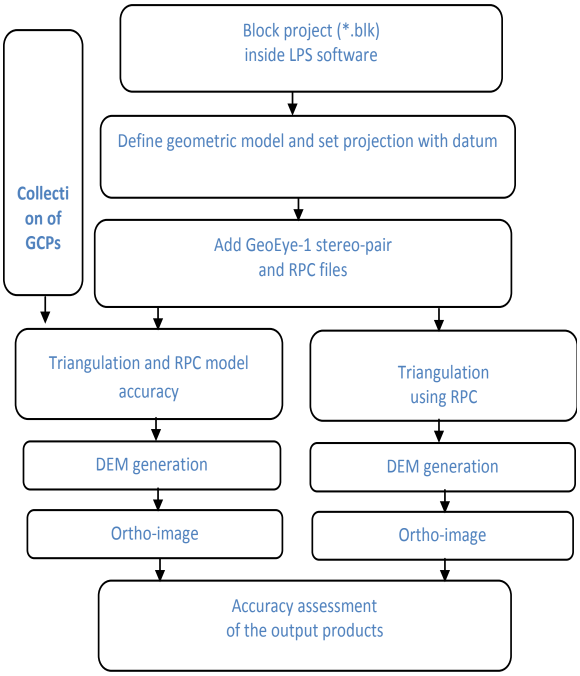

Figure-2: Schematic description of the methodological aspects

As interior and exterior orientations parameters are read from the RPC files by the software, both the orientations were performed automatically corresponding to the RPC files in frame editor. RPC model accuracy test was done using RPC and check points with and without GCPs as refinement parameters. The GeoEye-1 data was triangulated using GCPs and without GCPs after generating tie points. The tie points were generated automatically and triangulation was run with zero order polynomial for refinement of model.

After performing the triangulation, both the absolute and relative DEMs of 2m cell size were extracted with GCPs and without GCP respectively. The corresponding ortho-images with 0.5m resolution were generated using the extracted DEMs. The aft scene of GeoEye-1 has been used for ortho-rectification due to its viewing angle closer to nadir. Accuracy test has been done using the measured statistical records derived from the generated DEMs and ortho-images.

4. Results and Discussions

4.1: RPC model accuracy

The DEM has been generated using RPC model and GCPs for refinement of the model. In the first step, the block was adjusted without control points but using RPCs. Then the accuracy of RPC model is checked with 1, 2, 3 and 11 GPS survey points. The same process was introduced with 1, 2, 3 and 4 GCPs with 10, 9, 8 and 7 check points simultaneously. RMS were calculated for X, Y and Z values. The results for RPC model accuracy are shown in Table-2. The results indicate that the RMS horizontal errors lies within 2m when no GCPs are used and the errors are around 0.6m when the GCPs are used. The DEM results were compared with the CP's elevation. When no GCPs were used in the RPC model, the CP RMS vertical error was approximately 6m and the errors reduced to 1.25m when GCPs are used.

Table 2: Accuracy of RPC block file

No. of GCPs	No. of CPs	CPs RMS Error(m)		
		X	Y	Z
0	1	2.41	1.74	5.72
0	2	2.13	2.18	5.94
0	3	1.94	2.34	5.95
0	11	2.56	1.61	5.16
1	10	0.59	0.9	1.28
2	9	0.62	0.95	1.29
3	8	0.67	1.06	1.17
4	7	0.63	0.98	1.25

4.2. Accuracy Assessment of DEM

To validate the accuracies of DEM generated through GeoEye-1 data, the check points measured by GPS surveying techniques were used. Accuracy assessment was done by using 4 check points. The results are shown in Table-3. The column 2 shows the height at GPS survey points from DEM and column 3 shows the height measured by GPS survey for the same points. Then the difference between them was calculated. It is seen that difference varies from -1.17 to + 1.43m against the used 7 control points and -0.25 to 0.76 against 4 check points. The respective RMS are 0.75 and 0.44.

It has been observed that while using only RPC information for GeoEye-1 stereo data, the shift in height was around 5m compared to DEM for GCPs. The GCP-7 has been taken for the peak of a hill. It is seen that the height generated by RCP alone is under estimated by about 21 m compared to that generated by using GCPs. This implies that the height fields in the hill tops are not captured well without GCPs. Check points were underestimated by around 3 to 6.7m.

Beside the GCP-7, the height accuracy of some other hill tops has been tested with DEM generated for RPC only, where the surveyed heights were found to be higher ranging from 10m to 22m. It may be noted that use of more number of GCPs over topographically diversified areas with special emphasis for high terrains would improve the DEM accuracy.

Table 3: Comparison of height from generated DEM at control and check points using GCPs/RPC's

Points	Z Height (m) EGM2008 (from DEM)	Z' Height (m) EGM2008 (from GPS)	Height Diff. (m) Z-Z'	Z" Height (m) EGM2008(from DEM generated using RPC)	Height Diff. (m) Z'-Z"
GCP1	24.1663	24.1663	-0.000003	18.3264	5.8399
GCP2	28.1744	28.2764	-0.101995	21.6045	6.6719
GCP3	18.0465	17.4145	0.631985	14.4524	2.9621
GCP4	30.0901	30.4631	-0.373010	25.1452	5.3179
GCP5	30.7097	30.7097	0.000009	25.1628	5.5469
GCP6	43.4373	44.6093	-1.171998	38.2274	6.3819
GCP7	72.7792	71.3522	1.427000	50.3973	20.9549

Ckpt 1	34.7209	34.4049	0.315995	28.0789	6.3260
Ckpt 2	24.8453	24.0853	0.760006	20.8434	3.2419
Ckpt 3	19.3568	19.6138	-0.256986	15.5239	4.0899
Ckpt 4	24.1125	23.9595	0.153005	18.0826	5.8769

4.4 Assessment in planimetric shift of the ortho-products obtained with and without GCPs

The ortho-images of 0.5m cell size were generated from the DEM of 2m resolution with and without GCPs. Accuracy assessment was made by comparing the planimetric shift (X and Y directions) between the generated ortho-images. As shown in the table 4, nine points were picked up from the images as shown in figure-1 with crosses. The coordinate values were recorded by positioning the cursor on the pixels of similar object features from both the images. The shift in X and Y directions were calculated for these selected 9 points. The improvements in locational positioning in X and Y after using GCPs has occurred through the shifting by 2.67m and 1.21m respectively as indicated by the RMS value of the shifts.

Table-4: Location of 9 points corresponding to object features and their differences

Pt. ID	Location (X/Y) of Ortho-image using GCPs	Location (X/Y) of Ortho-image without GCPs	Diff. in X(m)	Diff. in Y(m)
1	701785.87/ 2443618.64	701783.00/ 2443618.60	2.87	0.04
2	704557.88/ 2443604.12	704555.26/ 2443602.92	2.62	1.20
3	706843.86/ 2443580.62	706841.49/ 2443578.71	2.37	1.91
4	701665.37/ 2438385.16	701662.41/ 2438384.95	3.81	0.28
5	704998.86/ 2438708.37	704996.40/ 2438707.35	2.46	1.02
6	707411.38/ 2439046.15	707409.27/ 2439044.05	2.11	2.10
7	702146.38/ 2433957.64	702143.36/ 2433957.80	3.02	-0.66
8	705185.89/ 2433771.66	705183.11/ 2433770.57	2.78	1.09
9	708135.87/ 2433851.29	708134.53/ 2433850.29	1.34	1.00
RMS			2.67	1.21

5. Conclusions

The study on the accuracy of DEM and ortho-image generation using the GeoEye-1 stereo PAN image has the following major findings.

The evaluation of RPC model accuracy indicates that the RMS horizontal errors lie within 2m without GCPs and around 0.6m with the GCPs.

The validation of DEM using GCPs against ground measurement shows that the RMS of deviations for 7-GCPs points are 0.75 and that for 4 control points 0.44.

DEM using only RPC has a shift in height of around 5m with respect to those using GCPs. Some chosen hill tops have been tested with DEM generated for RPC only, where the surveyed heights were found to be higher ranging from 10m to 22m. This implies that the height fields in the hill tops are not captured well without GCPs.

In addition the above, the planimetric shifts between the generated ortho-images with and without GCPs were found to be 2.67 and 1.21m respectively.

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