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Generation of DEM and Ortho-image from High Resolution Stereo Satellite Data for a selected part of Southeast Bangladesh

KEYWORDS GeoEyes-1, Triangulation, GCPs, DEM, ortho-image, positional accuracy.

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ABSTRACT *In the present study, Digital Elevation Model (DEM) has been generated from clipped part of GeoEye-1 PAN stereo pair of 0.5m resolution for selected hilly areas of Chittagong district. GPS survey has been conducted to collect Ground Control Points (GCPs) for satellite triangulation. DEMs and corresponding ortho-images with GCPs and without GCPs were generated using the scientific Leica Photogrammetry Suite (LPS) software. The accuracy has been assessed and compared. The overall RMSE for satellite triangulation using GCPs has come to 0.09535 pixels (0.05m). Accuracy of 0.0577m, 0.0540m and 0.335m was achieved in X, Y and Z directions respectively. The vertical accuracy of 0.2970m has been estimated using independent check points. The evaluation indicates that the relative DEM underestimates the absolute DEM by a height of around 5.2m. The study shows that the generated DEMs provide useful information on positions, distances and areas of three dimensional hilly regions.*

1. Introduction

Digital Elevation Models (DEMs) and Digital Surface Models (DSMs) have large relevance in some applications like modeling of water flow, water management, topographic mapping, developing GIS, natural hazards management, spatial and temporal change detection, environmental study and many other applications [1] (Deilami and Hashim, 2011). A new commercial VHR satellite called GeoEye-1 [2] (GeoEye, Inc., 2009) was launched in 2008 which provides images of highest geometric resolution, in panchromatic (0.41 m at nadir) and in multispectral (1.65 m at nadir) products. However, image products from GeoEye-1 have to be down-sampled to 0.5 m and 2 m GSD, panchromatic (PAN) and multispectral (MS) respectively, for commercial sales. In this way, the first geopositioning accuracy results attained in the orientation stage from GeoEye-1 PAN stereo-pairs were superior enough to those obtained from older satellites such as Ikonos or QuickBird [3] (Manuel et al., 2012).

GeoEye-1 has exhibited georeferencing accuracy as high as 0.1m (0.2 pixel) in planimetry and 0.25m (0.5 pixel) in height in very well controlled metric evaluation tests involving stereo image pairs and triplets [4] (Fraser & Ravanbakhsh, 2009), whereas [5], Mitchell and MacNabb (2010), working again onto a GeoEye-1 stereopair, 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.

This study attempts to generate high resolution DEMs and corresponding ortho-images from VHR satellite stereo-image for a selected part of hilly area situated in southeast Bangladesh. It is worth mentioning that, DEM with such high resolution is not available at all for this region of the country like Bangladesh. So, valuable information about a terrain can be obtained by exploiting the satellite based 3D products using appropriate technique.

2. 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 longitudes and latitudes, which covers a total area of 130km^2 approximately (Figure-1). The whole area is situated under three administrative units, namely, Banshkhali, Lohagara and Satkania Upazilas (sub-districts) of Chittagong district. The area encompasses the landscape with plain open space, agriculture fields and homestead areas, a few water bodies and comprises hilly region with ground height ranging from 3m to115m from Mean Sea Level (MSL).

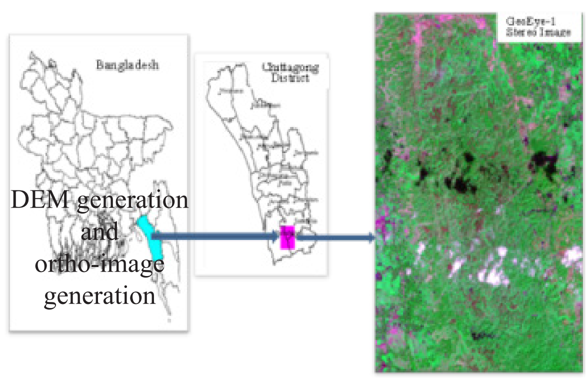

Figure-1: Shows the study area and the image

3. Data used

3.1. GeoEye-1 Stereo Data

A clipped part of 130 km^2 area from GeoEye-1 GeoStereo 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 by a sensor camera model along with corresponding rational polynomial coefficients (RPCs). The panchromatic and multispectral in-track stereo pair was acquired on 11 April 2012 with 121.76/122.16 and 66.26/66.47 degrees of sun azimuth and elevation respectively. The fore and aft scenes were collected with nominal collection azimuth of 4.63 degrees and 210.93 degrees and elevation of 62.78 degrees and 62.78 degrees respectively.

3.2 GCP data collection

Field survey was conducted for collection of GCPs data with a single frequency mode ProMark3 RTK GPS with Geographic projection and WGS84 datum. According to [6] Aschenbach

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2009, the computed accuracy of single frequency PM3 GPS is to a meter or less in the vertical and horizontal directions respectively. Data was collected at different heights from which 7 GCPs were used as control points to refine the model and 4 GCPs were used as check points for verifying the accuracy.

3. Methodology for DEM Generation

Leica Photogrammetry Suite (LPS) version 9.3 software is used to generate DEM, ortho-rectified image, editing of generated DEM, image mosaicing and calibration.

The methodological steps for the study 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. 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. Later, the GeoEye-1 data was triangulated using GCPs and without GCPs after automatically generated tie points.

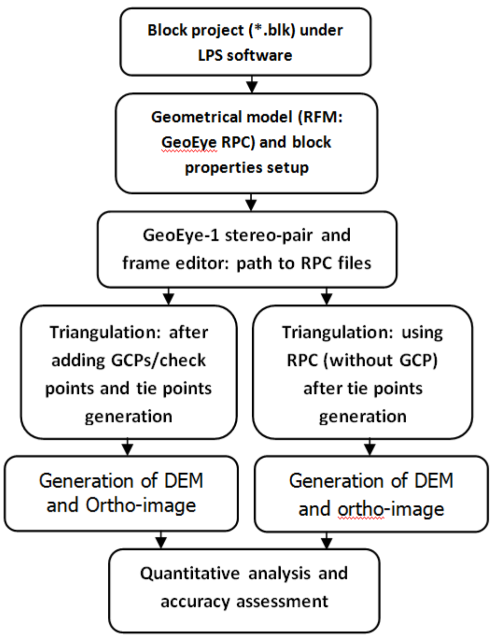

Figure-2: Schematic description of the methodological aspects of DEM and Ortho-image preparation

After running triangulation process, the absolute DEM (with GCP) with cell size of 2m were extracted and it was then used for generation of ortho-image. The resolution of the ortho-image was set to 0.5m. The generation of both the relative DEM (without GCP) and corresponding ortho-image in LPS 9.3 follows the same procedure as shown in the flow chart (Figure-2). In the next step the quantitative analysis of the accuracy has been performed.

4. Results and Discussions

4.1. Output results for satellite triangulation using RPC and GCPs

For generation of relative DEM, tie points were generated assigning the standard distribution pattern and then triangulation was run for refinement of the model. The refinement summery without using GCP indicated a total image RMSE of 0.1072 pixels (0.054m). The summery with seven GCPs showed that, the overall RMSE has come to 0.09535 pixels (0.0477m). Horizontal accuracy of 0.0577 m and 0.0540 m was achieved in X and Y directions respectively and the attained vertical accuracy was 0.3335 m. The vertical accuracy of 0.2970 m has been assessed by using independent check points. The image residuals of measured check points and intersected GCP are ax= 0.000, ay=0.000; mx= 0.061 my=0.014; ax=0.071, ay=0.131and mx=0.171, my=0.271. Where, the ax and ay values reflect the mean error for control and check points in X and Y coordinates respectively and the mx and my values reflect the root mean square errors of all control and check X and Y coordinates respectively.

4.2 DEM and Ortho-image evaluation using check points

Checkpoints are points having known ground positions and are used for assessing the accuracy. Model RMSE is indicative of modeling and GCPs' accuracy whereas check point RMSE reflects restitution accuracy, which conveys the feature extraction error and indicates for final positional accuracy of planimetric features [7] (Giribabu, et al., 2013).

Table-1: Evaluation of DEM and ortho-image accuracy using check points

Sl. No.	GPS Observations			Ortho-image observations		
	Longitude(m)	Latitude(m)	Height(m)	Longitude(m)	Latitude(m)	Height(m)
Chkpt1	708885.518	2437207.73	34.4049	708885.546	2437207.79	34.7208
Chkpt2	704180.431	2432006.54	24.0853	704180.58	2432006.55	24.8452
Chkpt3	702766.765	2437385.95	19.6138	702766.526	2437385.76	19.3717
Chkpt4	706974.493	2441226.15	23.9595	706974.282	2441226.29	24.1125
Sl. No.	Longitude errors(m)		Latitude errors(m)		Height(m)	
	Diff.	Square	Diff.	Square	Diff.	Square
Chkpt1	-0.0279	0.00078	-0.0588	0.00346	-0.3159	0.09979
Chkpt2	-0.1491	0.02223	-0.0081	0.00007	-0.7599	0.57745

Chkpt3	0.2385	0.05688	0.1907	0.03637	0.2421	0.05861
Chkpt4	0.2109	0.04448	-0.1357	0.01841	-0.153	0.02341
RMSE(m)		0.08619		0.04374		0.29701

Four check points were used as reference values in the triangulation process for accuracy assessment of DEM by means of check points RMSE. The obtained RMSE were 0.086 m, 0.044 m and 0.297m in the horizontal (X, Y) and vertical (Z) respectively. Differences of coordinate values for the check points between GPS and ortho-image observations in all X, Y and Z directions have been calculated and shown in Table-1.

4.3. Comparison of relative DEM with respect to absolute DEM

For absolute DEM, the rational function model (RFM) was used to correct the GeoEye-1 image GCPs. 4 check points were used to verify the accuracy. The GCPs were acquired with Geographic projection and WGS84 datum. A total of 7 GCPs were used as control points to refine the model and 4 were used as check points for verifying the positional accuracy.

Using GCPs, a 0.13m Circular Error 90% (CE90) in planimetry and a 0.59m Linear Error 90% (LE90) in height accuracy were attained against specified 2m Circular Error (90% (CE90) in planimetry and a 3m Linear Error 90% (LE90) in height of GeoEye-1 stereo with no ground control points. The above achieved/attained results show improvement of geopositional accuracy both in planimetry and in height with supplemental ground control points.

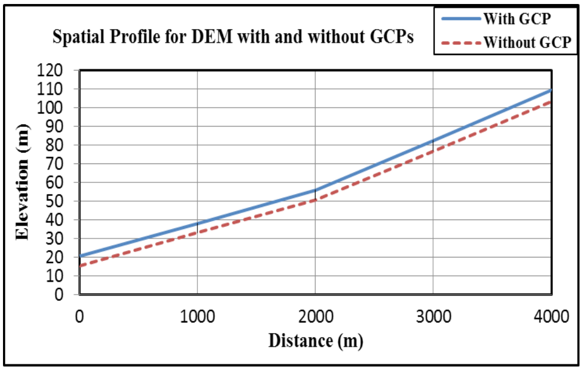

Figure-3: The variation of elevation with and without GCPs along a transect

Using GCPs, a 0.13m Circular Error 90% (CE90) in planimetry and a 0.59m Linear Error 90% (LE90) in height were attained against specified 2m Circular Error (90% (CE90) in planimetry and a 3m Linear Error 90% (LE90) in height with no ground control points. The above achieved/attained results show a great improvement of geopositional accuracy both in planimetry and in height with supplemental ground control points (GCPs).

The elevation profiles of the relative DEM was compared with that of absolute DEM using the graph presented in Figure-3. The dotted red line represents the heights of relative DEM and the solid blue line represents that of absolute DEM. It is observed that the relative DEM is underestimated by around 5.2m compared to the absolute DEM.

5. Conclusions

1) In the present study, DEMs have been generated from a clipped part of GeoEye-1 PAN satellite imagery with horizontal resolution of 0.5m for a selected area located in southeast Bangladesh. The DEM and ortho-image have been prepared using RCP, which has been corrected using GCPs collected from the study area using a single frequency ProMark3 GPS.
2) The refinement summery without using GCP indicated a total image RMSE of 0.1072 pixels (0.054m). The summery with seven GCPs showed that, the overall RMSE has come to 0.09535 pixels (0.0477m). Horizontal accuracy of 0.0577 m and 0.0540 m has been achieved in X and Y directions respectively and the attained vertical accuracy was 0.3335 m. The vertical accuracy of 0.2970 m has been assessed by using independent check points.
3) It is expected that use of more accurate and uniformly distributed GCP data will improve the results.

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