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Generation of DEM and Contour from High Resolution Satellite Data

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***Abstract**: The availability of stereo data from satellite significantly changed the way in which satellite images may be used. Presently, satellite images can be used for various applications in civil engineering. Satellite stereo data plays an important role in water resources application which uses the terrain surface and the contour data for slope analysis by automatic generation of Digital Elevation Model (DEM) from aerial triangulation (AT), mission planned satellites like IKONOS, QB, GeoEye and Cartosat provide the metric quality data. In this research work, it is proposed to use high resolution satellite stereo data i.e. GeoEye-1. Survey data like toposheets and ground control points were used in this research work, for analysis and accuracy assessment. This paper introduces with the typical workflow in photogrammetric areal triangulation, DEM and contours using Leica Photogrammetry suite (LPS) and Global mapper as a platform interactive and automated procedures were used. During image points matching, some processing on the original images has been done because in most bright and dark areas, such as mountain area, the feature identifications is difficult and it directly leads wrong matching results. We used Wallis filter (Wallis, 1970) for an adaptive nonlinear local contrast enhancement. This enhancement produces good local contrast throughout the image, while reducing the overall contrast between bright and dark areas. To generate the contours some interpolation technique is used to where the contours are generalized at the shadow portion.*

***Keywords**: DEM; AT; LPS*

I. Introduction

During the last two decades the space age has made a remarkable progress in utilizing remote sensing data to describe, study, monitor, and model the earth's surface and interior. Improvements in sensor technology, especially in the spatial, spectral, radiometric and temporal resolution, have enabled the scientific community to operational the methodology. The end of development of remote sensing is being from panchromatic, multi-spectral and hyper-spectral to ultra-spectral with the increase in spectral resolution. On the other hand, present spatial resolution is impressed to sub-meter for example 0.5m from GEO- Eye.

Generating a geometric sensor model for those images with ancillary data, such as SPOT 4 & 5. Because some high-resolution satellite images only provide RPC (rational polynomial coefficients) as geometric sensor model, in order to keep identical with this sensor model, they have taken RPC as the final geometric sensor model in the DEM generation procedure. After preprocessing (Vassilopolou et al., 2002; Fraser, 2002) which depends on the image quality as well as final use of DEM, mathematical models are used to georeference the stereo images Ground control points or image tie points are used to refine these geometric sensor models. After refinement, these geometric sensor models can be used in later processing.

II. Study Area and Data Used

The extent of study area lies between longitude 92°44' to 92°50‘ E and latitude 25°36' to 25°43‘ N. of Assam. The present study area covers both plain and hilly terrain. The metadata and details of study area is shown in the fig. 1. The data used is GeoEye-1.

GeoEye-1:

- GeoEye-1, which set the standard for sub-half meter high resolution commercial satellite imagery.
- GeoEye-1, the highest resolution and most advanced commercial imaging satellite in the world, offers unprecedented spatial resolution.
- It creates this accuracy by simultaneously acquiring 0.41-meter panchromatic and 1.65-meter multispectral imagery.
- The satellite can collect up to 700,000 square kilometers of panchromatic imagery per day (and up to 350,000 square kilometers of pan-sharpened multispectral imagery).

Input data:

- Control points GCP in .dat format.

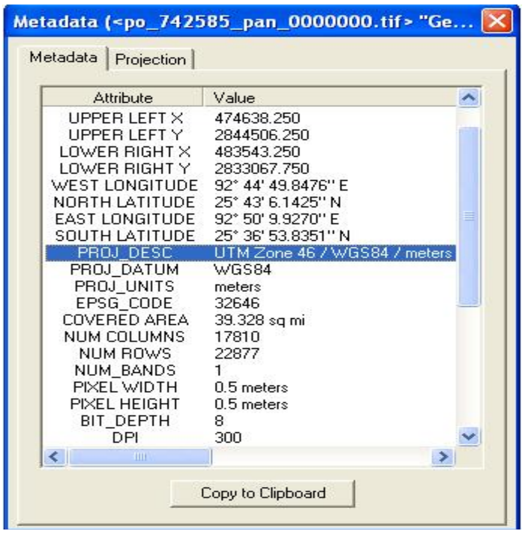


Fig. 1: Details of Study Area.

III. DEM Generetion From High Resolution Data

The original scenes have been resampled according to Epipolar Geometry. The resampled scenes exhibit two main properties. First, conjugate points are located along the same rows. Second, the x-parallax between conjugate points is proportional to the height of the corresponding object point. The following sub-sections briefly discuss the utilization of the normalized imagery for DEM generation. The generation process involves four steps: Primitive extraction, Primitive, matching, Space intersection, and Interpolation.

Primitive Extraction

At this stage, a decision has to be made regarding the primitives to be matched in the normalized scenes. Possible matching primitives include distinct points, linear features, and/or homogeneous regions. In this thesis, point features are chosen. Forstner interest operator (Forstner, 1986) is used to extract distinct points from the imagery. The operator identifies points with unique grey value distribution at their vicinity (e.g., corner points and blob centers), thus reducing possible matching ambiguities.

Primitive Matching

The outcome from the interest operator is a list of distinct points in the left and right scenes. The solution to this problem can be realized through defining the location and the size of search space as well as establishing matching criteria for evaluating the degree of similarity between conjugate points.

Space Intersection

Following the matching process, conjugate points undergo an intersection procedure to derive the ground coordinates of the corresponding object points. The parallel projection formulas are used for such computation. For a conjugate pair in the left and right scenes, one can formulate four equations with three unknowns (X, Y, Z - the ground coordinates of the corresponding object point). These coordinates are derived through a least-squares adjustment procedure.

Interpolation

The ground coordinates of matched interest points, which passed the consistency check, are derived through space intersection. These points are irregularly distributed and are not dense enough to represent the object space. Therefore, they need to be interpolated. In this thesis, Kriging is used to interpolate the resulting object space points into regular grid. The Kriging methodology derives an estimate of the elevation at a given point as a weighted average of the heights at neighboring points. However, the weights are stochastically derived based on the statistical properties of the surface as described by the elevations at the matched interest points (Allard, 1998).

IV. Methodology and Flow chart

Once the proper selection is made the stereo pair has to be oriented/ triangulated using sensor parameters and Ground control points to generate orientations In this research work digital photogrammetric techniques has proposed to use for generation of DEM and Contour. A flowchart of methodology for generation of DEM and Contours is shown below.

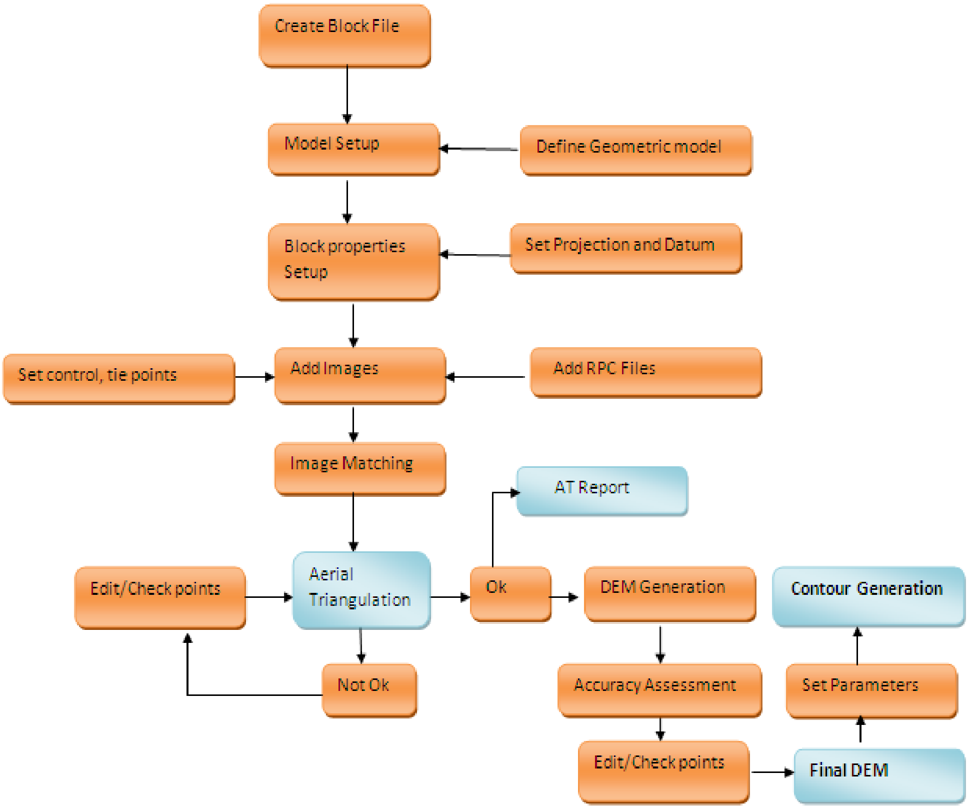


Fig. 2: Flow chart Generation of DEM and Contours

V. Final Extracted DEM and Contours

The Digital Elevation Model is extracted by considering all the stages as shown in the above flow chart. The generated contour and DEM (3D View) is shown in figure 3 and figure 4.

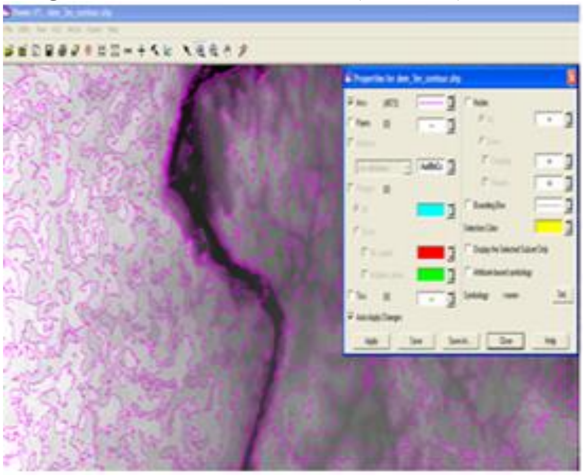


Fig. 3: A portion of generated contour from DEM

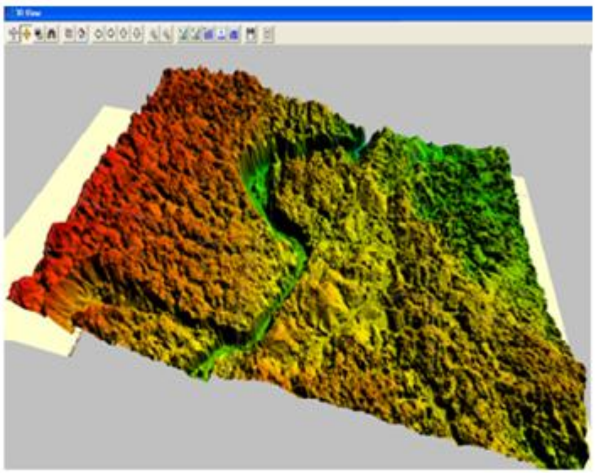


Fig. 4: Generated DEM(3DView)

VI. Result Analysis and Discussion

Standard Error Analysis:

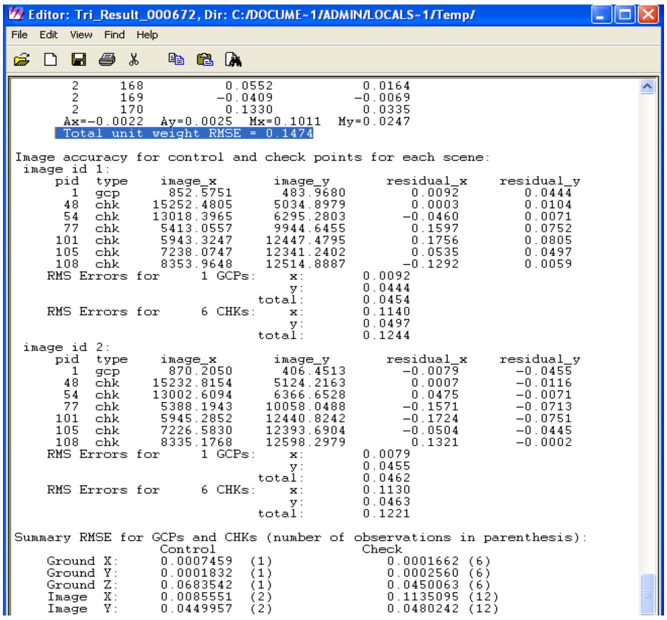
The results for each iteration of processing are calculated once the triangulation has been performed. This value is computed based on the image coordinate residuals for that particular iteration of processing. The computed standard error for each iteration accumulates the effect of each image coordinate residual to provide a global indicator of quality. The lower the standard error the better the solution.

RMSE & Image Coordinate Information:

Once the triangulation is complete, image coordinate residuals are computed. The residuals are computed based on the estimated exterior orientation parameters, GCP, check point, and tie point coordinates, and their respective image measurements. During the iterative least square adjustment, the results from the previous iteration are compared to results of the most recent iteration. During this comparison, image coordinate residuals reflecting the extent of change between the original image coordinates and the new values are computed. The values of the new image coordinates are dependent on the estimated or adjusted parameters of the triangulation. Therefore, errors in the estimated parameters are reflected in the image coordinate residuals.

Total Image RMSE:

Figure 5 displays the total root mean square error for the triangulation. Which is acceptable i.e? Below 0.2 especially for undulated areas. This standard deviation of unit weight is a global precision indicator describing the quality of the entire solution is acceptable.



```
Editor: Tri_Result_000672, Dir: C:/DOCUME~1/ADMIN/LOCALS~1/Temp/
File  Edit  View  Find  Help

     2      168           0.0552            0.0164
     2      169          -0.0409           -0.0069
     2      170           0.1330            0.0335
    Ax=-0.0022  Ay=0.0025  Mx=0.1011  My=0.0247
    Total unit weight RMSE = 0.1474

Image accuracy for control and check points for each scene:
 image id 1:
     pid  type    image_x       image_y       residual_x    residual_y
       1  gcp      852.5751      483.9680       0.0092        0.0444
      48  chk    15252.4805     5034.8979       0.0003        0.0104
      54  chk    13018.3965     6295.2803      -0.0460        0.0071
      77  chk     5413.0557     9944.6455       0.1597        0.0752
     101  chk     5943.3247    12447.4795       0.1756        0.0805
     105  chk     7238.0747    12341.2402       0.0535        0.0497
     108  chk     8353.9648    12514.8887      -0.1292        0.0059
    RMS Errors for      1 GCPs:     x:      0.0092
                                    y:      0.0444
                                total:      0.0454
    RMS Errors for      6 CHKs:     x:      0.1140
                                    y:      0.0497
                                total:      0.1244
 image id 2:
     pid  type    image_x       image_y       residual_x    residual_y
       1  gcp      870.2050      406.4513      -0.0079       -0.0455
      48  chk    15232.8154     5124.2163       0.0007       -0.0116
      54  chk    13002.6094     6366.6528       0.0475       -0.0071
      77  chk     5388.1943    10058.0488      -0.1571       -0.0713
     101  chk     5945.2852    12440.8242      -0.1724       -0.0751
     105  chk     7226.5830    12393.6904      -0.0504       -0.0445
     108  chk     8335.1768    12598.2979       0.1321       -0.0002
    RMS Errors for      1 GCPs:     x:      0.0079
                                    y:      0.0455
                                total:      0.0462
    RMS Errors for      6 CHKs:     x:      0.1130
                                    y:      0.0463
                                total:      0.1221

Summary RMSE for GCPs and CHKs (number of observations in parenthesis):
                  Control                    Check
    Ground X:     0.0007459  (1)               0.0001662 (6)
    Ground Y:     0.0001832  (1)               0.0002560 (6)
    Ground Z:     0.0683542  (1)               0.0450063 (6)
    Image  X:     0.0085551  (2)               0.1135095 (12)
    Image  Y:     0.0449957  (2)               0.0480242 (12)
```

Fig. 5: RMSE Result

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