ACURACY ASSESSMENT OF DTM DATA: A Cost Effective Approach for a Large Scale Digital Mapping Project

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ABSTRACT

Digital Terrain Model (DTM) is the most critical and cumbersome element of any large-scale digital mapping projects. Accuracy assessment of DTM data is an intricate and expensive process, since assessment data are collected utilizing either conventional or Global Positioning System (GPS) surveying techniques. In this paper a Photogrammetric technique has been suggested to acquire DTM assessment data instead of conventional or GPS surveying. In any Photogrammetric (digital or analytical) mapping aerial triangulation (AT) is a must to establish pass and tie points before the mapping project can proceed to the next step. In this paper it is proposed that while collecting the pass and tie points for AT some extra points (on the ground surface only) be collected in every model which can be used in assessing the DTM data. The bundle adjustment is run twice, one with the regular pass and tie points and the other with only the check/assessment points, thus the assessment points are not directly related with the photogrammetric process to calculate the six photogrammetric elements, i.e., assessment points will not have any direct correlation with the tie and pass points. A test site in suburban Atlanta containing three stereo models has been chosen for this study.

1 INTRODUCTION

Digital Elevation Model (DTM) collection is the most important and cumbersome part of any digital mapping project especially for large scale engineering mapping. In many engineering projects 60 cm (2 feet) and 30 cm (1 foot) contour mapping is required; meeting the National Mapping Accuracy Standards (NMAS) for such a large-scale mapping is challenging in terms of meeting accuracy as well as making the price affordable. At present, digital photogrammetry has matured and it can easily meet the required accuracy and keep costs low if it is performed properly.

DTM collection is an integral part of every day digital photogrammetry workflows. A Digital photogrammetry work flow is given here briefly to refresh the reader's memory: aerial photographs are captured using a high precision photogrammetric analog camera (e.g., WILD RC-30 with Forward Motion Compensation, air borne GPS, etc.), negatives or diapositives are scanned using high precision photogrammetric scanners (e.g., Intergraph's PS-1 or PSTD scanners) at high resolution (e.g., 14 and/or 15 µm) depending on the type (B/W or Color) of the film and scale of the negative and/or diapositive, ground control points are established on pre pointing panels or post pointing photo identifiable points using

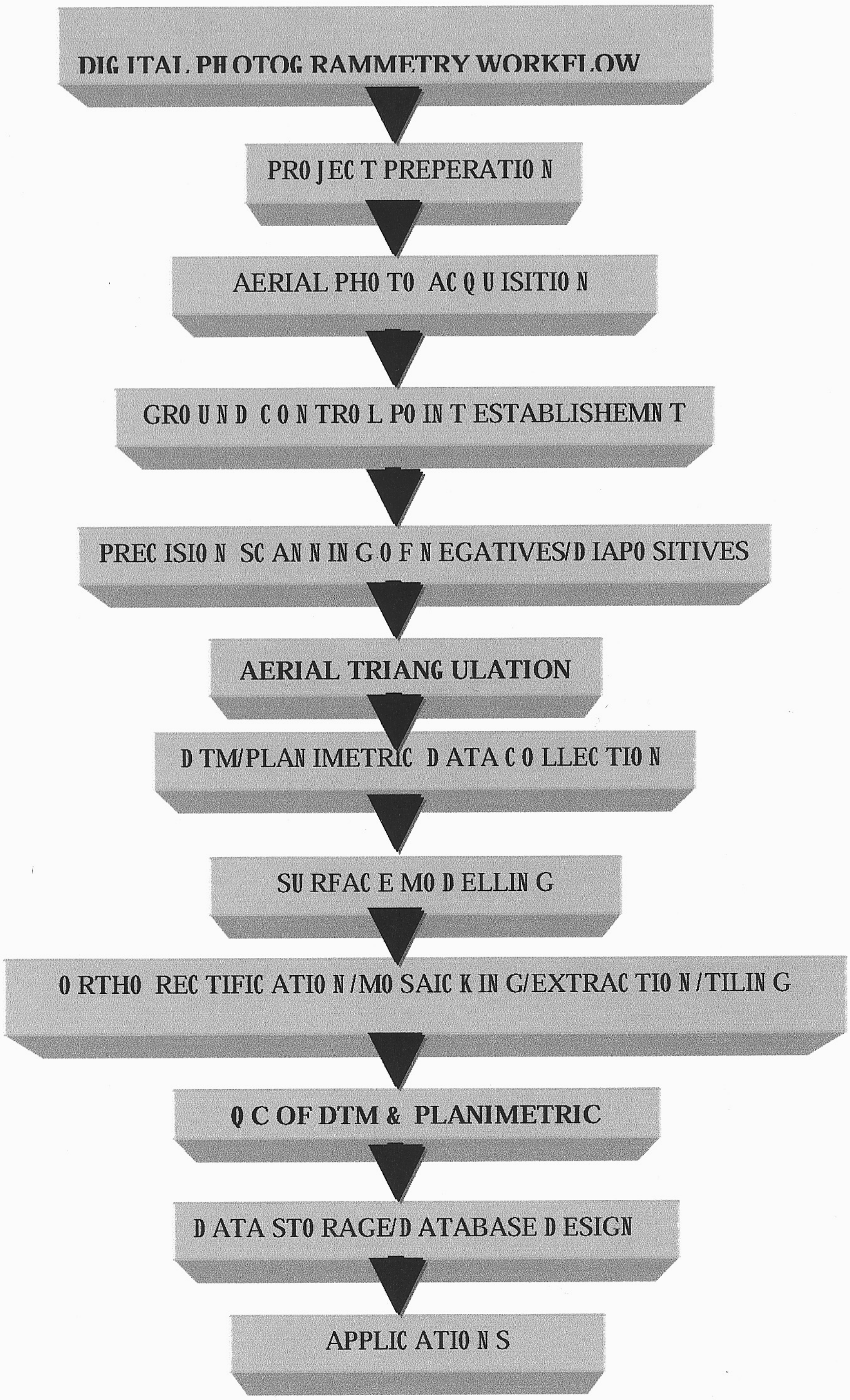

Figure 1: Digital Photogrammetry Workflow

GPS or conventional techniques), aerial triangulation is performed (using known control points as discussed above), the bundle adjustment of entire project is performed, epipolar resampling for stereo images is performed, DTM collection and planimetric compilation is done using these epipolar resampled images and utilizing stereo techniques (3-D mode), surface modeling is done to check the DTM data, ortho rectification is performed for every scanned image, ortho rectified images are checked against the photo control and ground control points to check the relative accuracy of the ortho rectified images. Although, a quality check is performed in every step of the digital photogrammetric processing, the final accuracy check is performed by establishing coordinates on well defined physical ground control points and comparing them with the photogrammetrically established elevation or planimetric data. Figure 1 provides a quick look at a present day digital photogrammetry workflow.

2 DTM COLLECTION TECHNIQUES

A Digital Elevation Model (DTM) is a set of X (Easting), Y (Northing), and Z (height) points on the surface of the earth. These points are usually used to generate topographical contour maps, surface modeling, volume computation, and engineering design work. To achieve and maintain the accuracy of the Z component of these points is a challenging and difficult job. DTM can be collected or generated using the following techniques:

- GPS or Conventional Surveying Technique
- Analytical/Analog Photogrammetry
- Digital Photogrammetry
- Non Imaging Airborne Techniques

2.1 GPS or Conventional Techniques

Depending on the size and location of the project both or either one of the techniques can be used for collecting DTM data. For example if a project site is smaller than 100 acre area and it is covered by tall trees and/or is an urban area, only conventional surveying techniques (total station) are optimal for such a project.

2.2 Analytical/Analog Photogrammetry

Until the last decade this technique was only a viable technique for topographical mapping of moderate to large sized projects. This technique is still in use in many projects. The cost is very high due to the manual process of DTM collection process.

2.3 Digital Photogrammetry

Manual Technique (Similar to Analytical Technique): DTM points are collected as random points and break lines and spot elevation points are collected throughout the model.

Semi Automatic Technique: DTM points are collected in a systematic grid mode and additional break lines and random points are added through out the model.

Automatic Technique: Automatic DTM points are collected using auto-correlation technique to a defined area of interest in the model. Obscured areas are delineated to exclude DTM collection areas where the auto-correlation would not work such as forested areas, buildings, and areas of minimum contrast. Also, break lines and random points can be added in the model as needed.

2.4 Non Imaging Airborne Techniques

Laser scanning is becoming commonplace in creating digital elevation models or digital surface models. Laser mapping produces data based on the elevation of top or bottom of any objects on the surface of the earth. In term of accuracy of the elevation data, these are equivalent to traditional GPS and surveying data. The main difference between these elevation measurement techniques is that laser mapping can produce these elevation data at a rate thousands of times faster than conventional techniques including digital photogrammetry.

3 AERIAL TRIANGULATION TECHNIQUES

This is the technique of performing Interior Orientation (IO), Relative Orientation (RO), Absolute Orientation (AO) to establish pass, tie, and check points using known ground control points. Digital photogrammetry performs "on-the-fly" orientation and control point (pass, tie, and checkpoints) densification for an entire project. Digital photogrammetry can save substantial time and increase precision of digital auto correlation technique, and thus precision of the DTM collection. Figure 2 shows a schema of RO point collection using analytical/analog photogrammetric technique. Figure 3 depicts a standard tie and pass point measurement schema using digital photogrammetric techniques.

4 TEST METHODOLOGY

Three stereo models (color negative scale 1:3000 scanned at 14 µm pixel size in the vicinity of Atlanta) were used to perform the test study. Figures 2 and 3 depict the typical analytical and digital photogrammetry schema for aerial triangulation to densify pass and tie points in the model area. Figure 4 is the proposed schema to include extra control points to check the accuracy/ precision/authenticity of DTM points collected by an operator in the model area or to the entire area for a given project. These check points can be used to check the accuracy of DTM points as well as the accuracy of orthophoto produced.

As shown in Figure 4, twenty one extra randomly selected well defined points were measured in every model, and a bundle adjustment was run separately for these check points ((it is very critical that these points should be measured on the ground surface, being the well defined points which can be seen on the ground photogrammetrically, the example objects are: intersection of roads, edge of parking stripe, bottom of power poles, any specific object which can be seen in the stereo pairs). The accuracy of these sixty three check points was better than three (3) centimeters in X, Y, and Z. The check or assessment points are not directly related with the photogrammetric process to calculate the six photogrammetric elements thus they can be assumed uncorrelated with the tie and pass points.

5 TEST RESULTS

All together sixty-three-check points were measured in three models and a bundle adjustment was run to get the coordinates. A check point file including all checkpoints was created with Point ID and X, Y, Z coordinates and saved as "XYZ" file. The check point file was used to test the DTM data collected on each model and for the merged DTM file. Running the check on each model can guarantee the accuracy of the DTM data and if there is any problem in any model it can be fixed right away. The test on the merged file (design file elements such as random points, break lines, and spot elevations were merged to create a merged project file with .ttn and .grd files) ensures the merging process and quality of the final DTM data. The test results are given in Table 3 for each model and for the merged DTM file. An earlier test results (Acharya 1996) on the DTM data collected (same scale B/W scanned photos at 21 µm) by different techniques is given in Table 1 and 2 to compare the results.

Table 1: Test of DTM Accuracy Using GPS Control Points (unit in m)

Methodology	No. of GPS Points Used	Minimum Difference	Maximum Difference	Mean Difference	Standard Deviation
Automatic Collection	500+	0.003	1.196	0.268	0.293
Analytical Collection	500+	0.000	1.829	0.140	0.215

Table 2: Test of DTM Accuracy Using Volume Computation (unit in m)

Methodology	Original Grid Size	Base Height Used (m)	Volume Computation (m^3)		Area Computation (m^2)
			Cut	Fill	
GPS DTM	50m x 20 m	200.00	6.46153×10^6	-------	147746
Manual DTM	20 m x 20 m	200.00	6.48011×10^6	-------	147923
Automatic DTM	5m x 5m	200.00	6.51288×10^6	--------	148867
Analytical DTM	Random Points	200.00	6.5867×10^6	-------	149630

Table 3: AT Check Points Test Results (unit in m)

Test Model	Number of Check Points Used	Number of DTM Points Tested	Mean Difference	Standard Deviation	Remarks
11-1-2	21	30,000+	0.22	0.18	DTM points were collected in semi-automatic mode and 10 feet grid was used
11-2-3	21	30,000+	0.27	0.18	"
11-3-4	21	30,000+	0.27	0.17	"
Merged File	**63**	**91,885**	**0.25**	**0.17**	"

6 CONCLUSIONS

The present study is a follow up to our earlier study. This study had two objectives: testing and comparing the accuracy of DTM collected using digital photogrammetry, and application of new approach to perform QC test using photogrammetric technique (Aerial Triangulation). Based on the test results from 1996 (Tables 1 and 2) and 2000 (Table 3), it can be safely concluded that the accuracy achieved in DTM data using digital photogrammetric techniques can be slightly better than using the analytical photogrammetric techniques. The study site was a mixed: an urban and wooded area, however it consistently indicated improvement in the accuracy of DTM data compared to the earlier study. The technique described in this paper if used can ascertain the quality of DTM data, and ortho rectified images and it is an economic method to perform this type of quality control tests. Also, it should be noted that the digital photogrammetric environment is critical to the scanning resolution (Ground Sampling Distance-GSD), quality of aerial photography (Ground Resolving Distance-GRD or line pair per millimeter), scale of photography, and software and viewing (resolution of monitor) system used to compete with the analytical system. The standard deviations in Table 3 are consistently better than the standard deviations in Table 1, which means if appropriate techniques and procedures are applied, the digital photogrammetric techniques can achieve better accuracy compared to an analytical DTM collection procedure. The technique described in this paper for QC test may cost only a fraction of the cost of performing similar test by using the conventional or GPS surveying technique.

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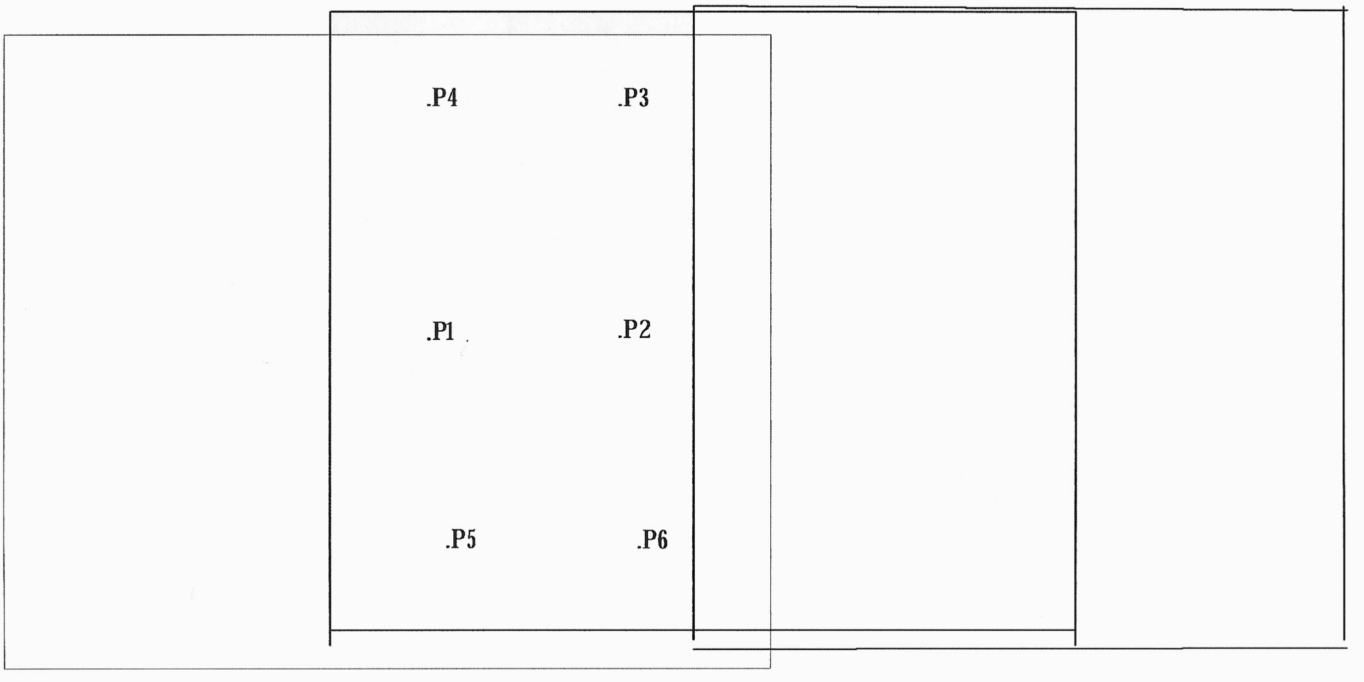

Figure 2: A Typical Photogrammetry R0 Point Selection Schema

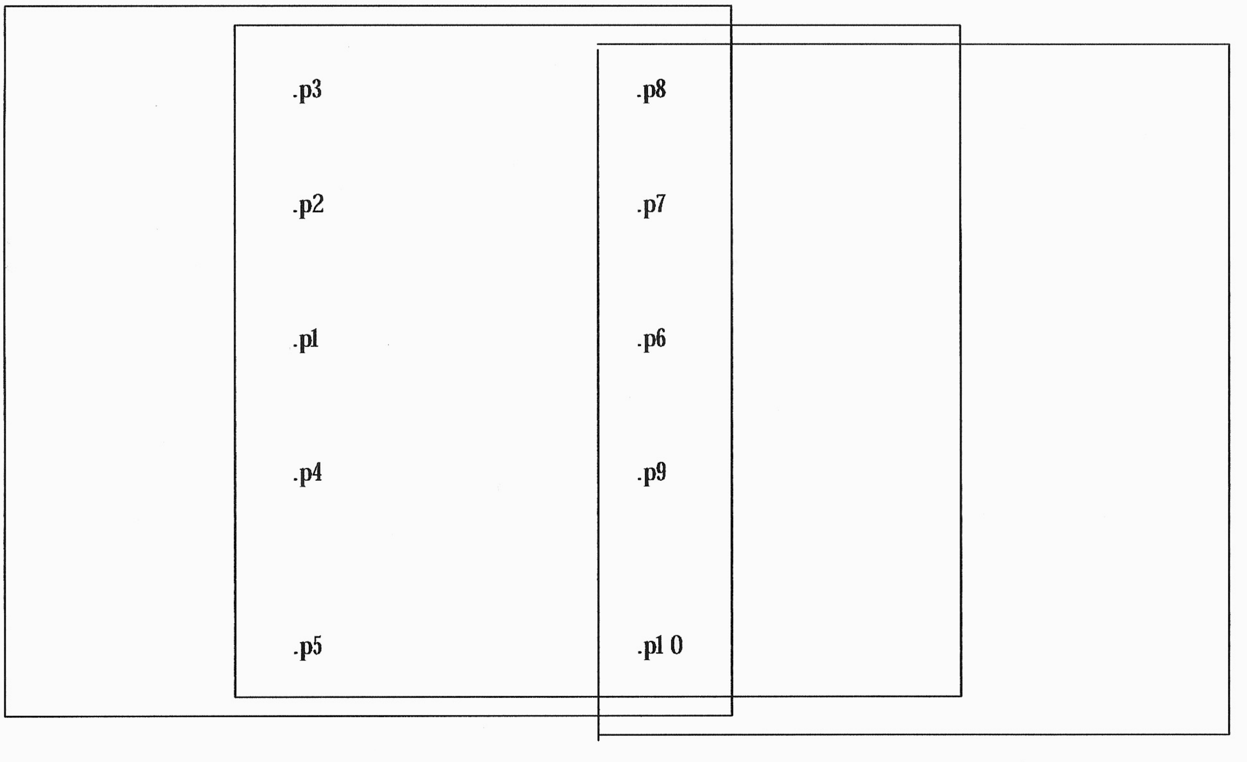

Figure 3: A D igital Photogrammetry R0 Point Selection Schema

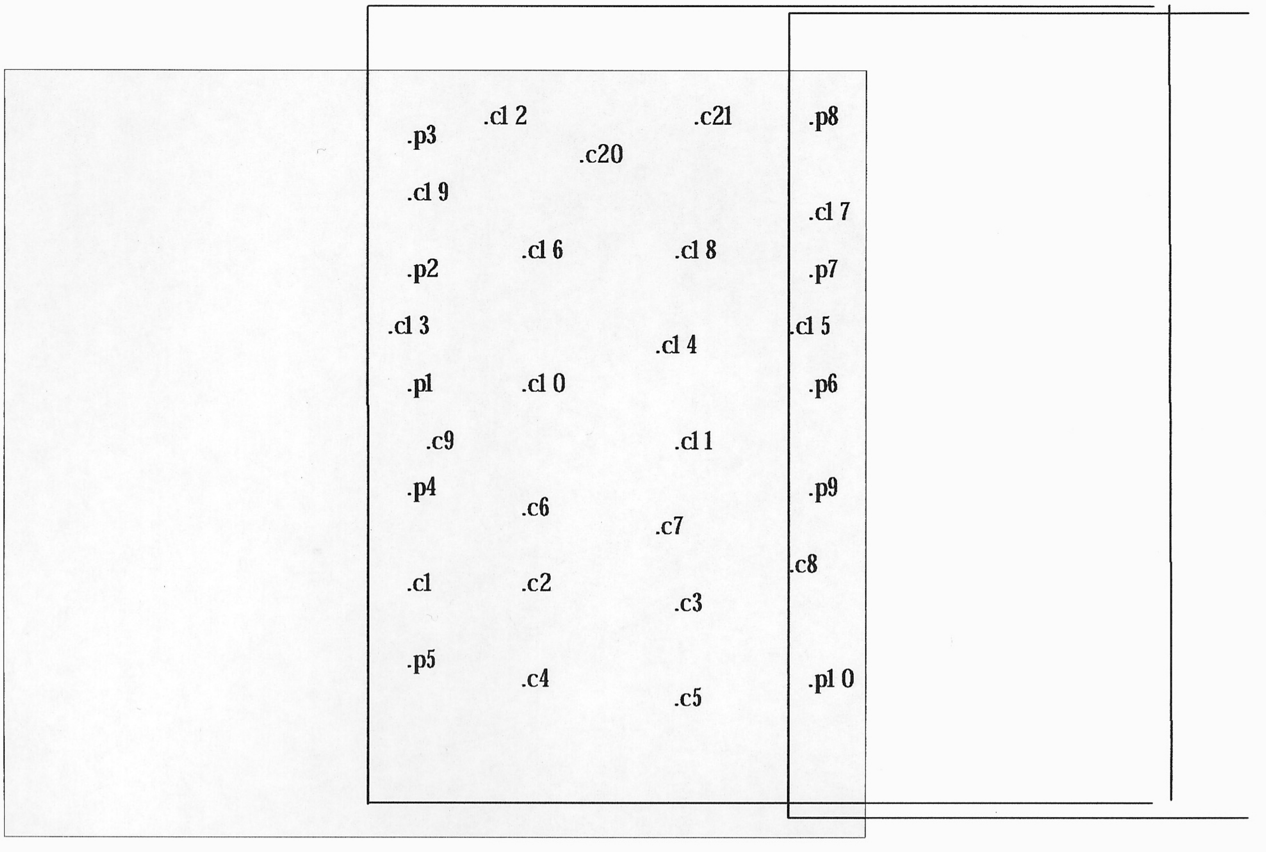

Figure 4: Proposed RO and Random Well Defined Point Selection Schema