INVESTIGATION OF AERIAL TRIANGULATION AND SURFACE GENERATION USING A SOFTCOPY PHOTOGRAMMETRIC SYSTEM

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ABSTRACT:

The accuracy of softcopy aerial triangulation and surface generation was investigated. The experiments were implemented using a high-end, commercially available softcopy photogrammetric system. Automated and semi-automated methods of data collection were used for point measurements, and surface generation. The results from the softcopy approach were compared to those produced by conventional analytical plotters.

The data set used for the experiment was a strip of 65 low altitude photography with a scale of scale of 1:3600. These photographs were scanned using two high-end photogrammetric scanners. Ground coordinates of 263 pug points were measured automatically and aerial triangulated using the softcopy systems. Surface elevation data were also automatically generated for a 5 photo subset of the strip. The surface data and triangulated pug points were compared to data measured manually and extracted using analytical plotters.

Analysis of these comparisons shows that accuracy of aerotriangulated points is better than 0.1 meters with a standard deviation of the differences between 0.1 and 0.2 meters. The average discrepancy between the two approaches in surface collection is close to zero, but the standard deviation in the automatically derived elevations are about 0.75 meter. This study concludes that, for large scale mapping, aerial triangulation results from softcopy systems are as accurate as those expected from conventional methods. This study also finds that the automatically generated elevation data are less accurate than that manually collected with an analytical plotter.

1. INTRODUCTION

A research project entitled “Research and Development in Softcopy Photogrammetry” has been underway for two years at the Laboratory for Softcopy Photogrammetric Systems of the University of Wisconsin-Madison.

This research has been funded by the Wisconsin Department of Transportation (WisDOT). The primary objective is directed at investigating critical aspects of softcopy photogrammetry and presenting recommendations to WisDOT as to develop strategies for conversion to softcopy technology. Aspects of this research involved a review of the state of softcopy technology, a survey of commercial photogrammetric systems, and a survey of photogrammetric scanners.

This paper describes experiments undertaken during the project to investigate the accuracy of aerial triangulation (AT) and surface generation implemented in a commercial softcopy photogrammetric system. The system investigated is the Leica Helava DPW770.

2. PROJECT DESCRIPTION

The photographic coverage and ground controls used in this research were provided by the Technical Services Office of WisDOT. WisDOT provided AT results and a digital terrain model (DTM). Both of these products were generated with analytical plotters using manual methods. The ground coordinates of 263 pug points along the strip were calculated using conventional AT. The DTM was collected using a Kern DSR-14 analytical plotter for a 5 photo subset of the strip.

The photographic coverage consisted of 65 photographs distributed over six strips, overlapping at the end of each strip, thus forming a snake-like block. The 65 diapositives were scanned with the Helava DSW200 at a resolution of 12.5 microns resulting in image files containing approximately 17,800 lines by 17,800 samples. The diapositives were also scanned with the Intergraph PS1, at resolution 15 microns, resulting in approximately 15,340 lines by 15,340 samples. These images are being used for an experiment with Intergraph that is still underway.

The positions of the 263 pugs on the images, as well as positions of pass points, were measured automatically using the Leica DPW 770. These measurements were carried out by the Leica staff.

Leica was asked to measure the location of the pugs but not to include these measurements in the solution of the AT. **This is to avoid incorporating in the adjustment the skill of the human operator, whose stereoscopic vision determined the conjugate locations of these pug points.** Using the AT output, ground coordinates of the pug points were calculated. They served as check points, by comparing them with their corresponding values, generated earlier with the conventional approach.

The WisDOT also supplied a DTM of 5 model subset of the strip. Points and break lines were collected manually using Kern DSR-14 analytical plotter. A file with 23,799 ground coordinates was produced.

A surface covering approximately the same area was generated automatically at regular intervals using the DPW 770, resulting in digital elevation model (DEM) files. Since the DTM points were not extracted at a regular interval, the corresponding points from the DEM had to be interpolated for meaningful comparison.

3. EXPERIMENTS AND RESULTS

3.1 Aerial Triangulation

AT files provided by WisDOT contained coordinates (X, Y and Z) of each of the pug points. These values were calculated using a WisDOT in-house AT procedure. These coordinates were compared to the corresponding values generated by each of the softcopy systems. The comparison results are listed in Table 1.

Table 1. A Comparison of the differences between the ground coordinates of pug points determined by conventional methods and the values determined by Leica.

	X	Y	Z
Average Difference (m)	0.01	-0.00	0.09
Variance (m)	0.078	0.084	0.049
S.D. of Difference (m)	0.01	0.01	0.22
RMS Difference (m)	0.08	0.08	0.24

Figure 1 is a plot of the deviations in Z between the Leica derived AT values and the values supplied by WisDOT. The differences are relatively small, but there are few points with deviations greater than 0.5 meter.

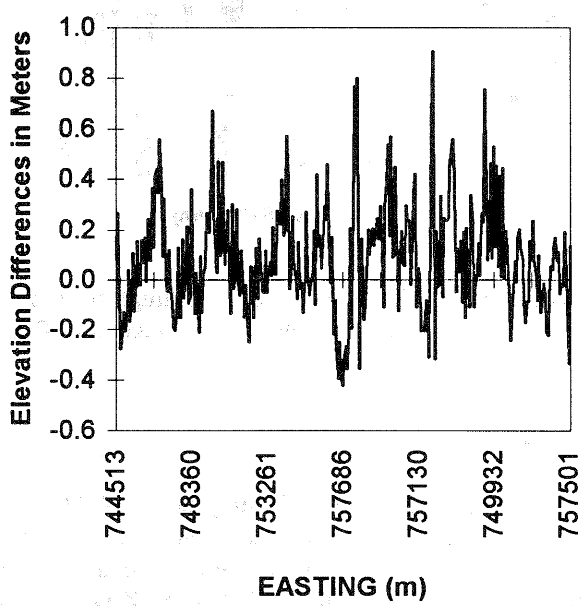

Figure 1. Differences in Z between WisDOT and Leica, calculated by AT, as a function of Easting along the strip.

The corresponding deviations in X (Easting) and Y (Northing) was also plotted as a function of Easting. These charts can be found in Figures 2 and 3. Examining the Figures 1 through 3, we can see that the deviations in X and Y are smaller than the deviations in Z.

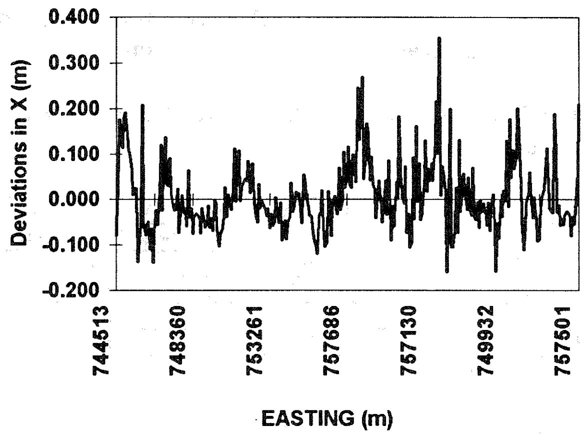

Figure 2. Difference in X (Easting) between the WisDOT and Leica AT values, as a function of Easting along the strip.

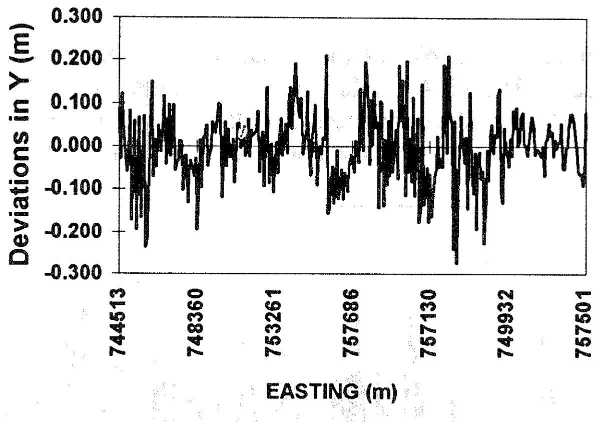

Figure 3. Differences in Y (Northing) between the WisDOT and Leica AT values, as a function of Easting along the strip.

3.2 Surface Generation

Two DEMs were generated using the DPW 770 with a grid spacing of 5 meters and 2 meters, respectively. Only the 2 meter DEM was compared to the WisDOT DTM file MIL23X. The 23,799 X, Y, Z values in the MIL23X were treated as check points. Elevations from the softcopy generated DEM were then interpolated using a bilinear interpolation at each DTM point, and then compared to its corresponding value in MIL23X. The differences are summarized in the first column of Table 2. Many of the points in MIL23X were derived from break lines.

The second column in Table 2 presents statistics of the comparison between the Leica DEM and the 4,405 points in MIL23X that were not derived from break lines (points marked "REG"). The "Difference" in this table refers to the value of WisDOT elevations minus the Leica elevations at the same spatial location.

Table 2. Comparison Statistics Leica's DEM and WisDOT's DTM.

	Elevation Points within WisDOT DTM	
	All Points	"REG" Points Only
Ave. Difference (m)	-0.08	-0.10
Variance (m)	0.57	0.51
S.D. (m)	0.75	0.72
RMS (m)	0.75	0.72
Number of Points	23,799	4,405

In order to investigate the large root mean square (RMS) differences that are evident in Table 2, a histogram of the number of points with a given difference was calculated. The histogram, shown in Figure 5, displays the frequency of points with a given difference versus the differences.

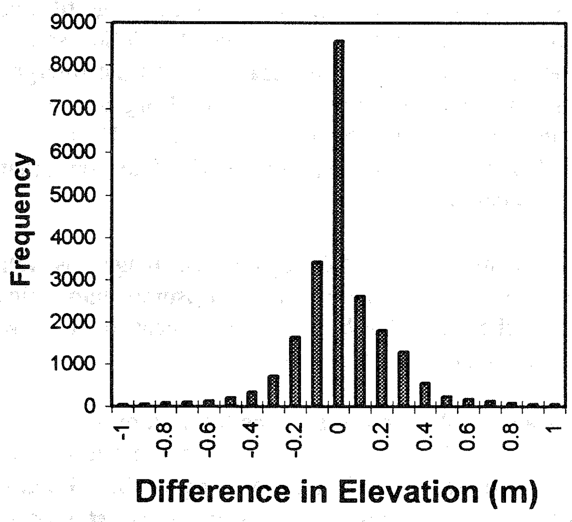

Figure 4. The frequency of points within the WisDOT DTM with a given difference in elevation between the WisDOT DTM and the Leica DEM.

The histogram shows that the differences are nearly equally distributed on either side of the mean difference. This may indicate that the models are tipped relative to each other. To further investigate, the Leica DEM and the interpolated DEM, that is derived from the WisDOT DTM, are visualized in Figures 5 and 6, respectively. The differences between these two DEMs are not evident from these figures.

In order to determine which of the DEMs is most likely correct, a further comparison was made between the elevations derived from the WisDOT AT values and the elevations from the two DEMs. Fifteen WisDOT AT elevation points (from the pugs) were found within each of the DEMs. Two of the points (73 and 78) were located toward the edge of a photograph. Table 3 shows statistics derived from comparing elevations within the Leica DEM to the WisDOT AT derived elevations. The first column presents the results from comparing all 15 WisDOT AT elevation values to the corresponding elevations derived from the Leica DEM. The second column contains the same comparison for the 13 WisDOT AT points away from the photo edges. Column 3 presents statistics of comparing the 15 Leica derived AT elevations to the corresponding elevations derived from the Leica DEM. Column 4 contains the same comparison in column 3, excluding points 73 and 78.

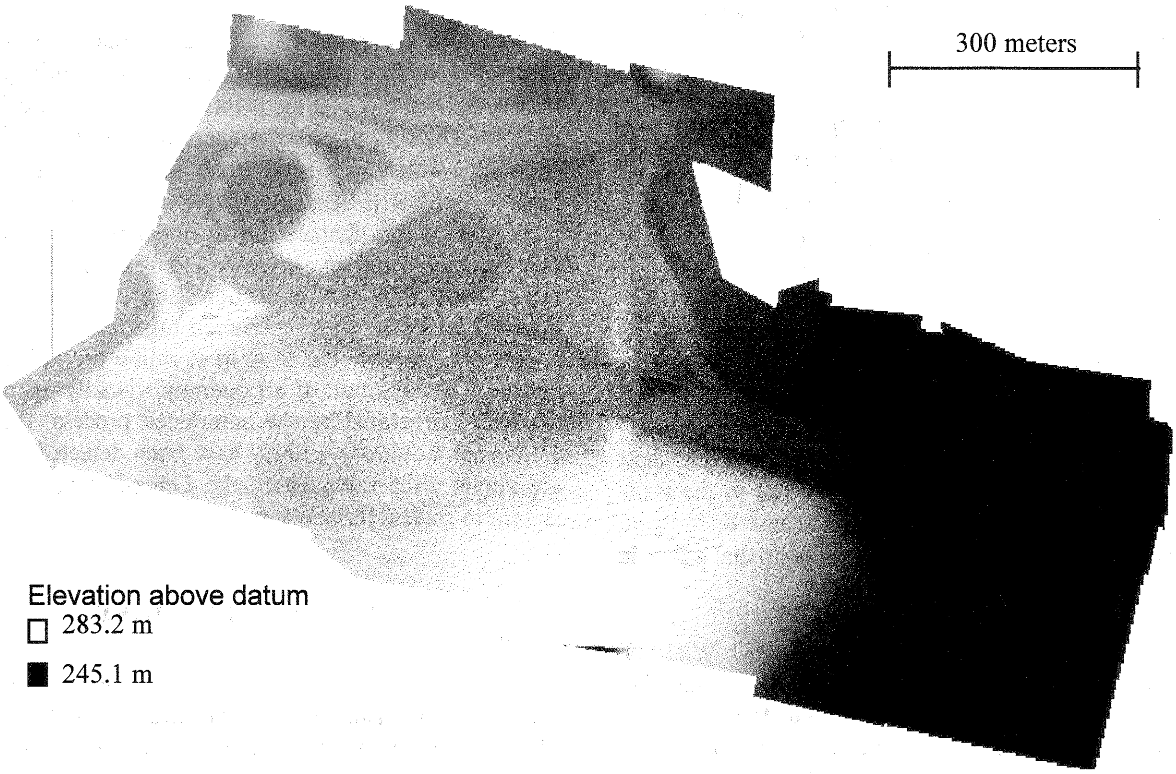

Figure 5. Visualization of the DEM produced by the Leica-Halva softcopy system with a 2 meter grid spacing. Lighter shades within the DEM indicate heigher elevation values.

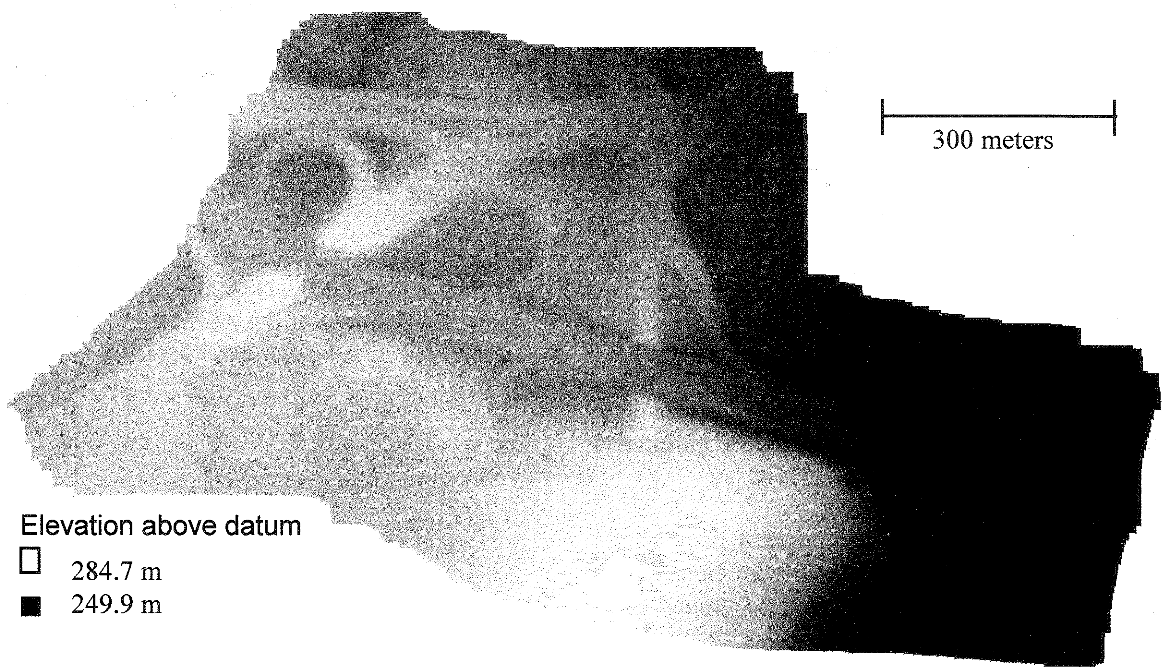

Figure 6. Visualization of the DEM produced on the Kern DSR-14 interpolated to a 1 meter grid spacing. Lighter shades within the DEM indicate higher elevation values.

Table 3. Statistics derived from the difference between AT calculated elevations and the Leica DEM elevations.

	WisDOT AT		Leica AT	
	15 Pts	13 Pts	15 Pts	13 Pts
Ave. Difference (m)	0.15	-0.08	0.11	-0.08
Variance (m)	1.21	0.04	0.99	0.03
S.D. (m)	1.07	0. 20	0.99	0.16
RMS (m)	1.07	0.17	0.96	0.13

The relatively high values of the standard deviation of the differences (and the RMS value of the differences) are consistent with data presented in Table 2. Since the large standard deviation occurs for both sets of AT derived coordinates, the discrepancies are not likely related to the AT calculations. The large decrease in the standard deviation for the 13 point sets seems to indicate that the model is not oriented properly or that there is some inconsistency within the model.

A further test was made by comparing the WisDOT DTM values with the AT derived elevations. This also required interpolating elevations from the WisDOT DTM that correspond to the same positions of the AT derived elevations. The WisDOT DTM encompassed a slightly larger ground area and 20 AT points were found within the DTM. The results of this comparison of differences between the AT calculated elevations and the interpolated elevations from the WisDOT DTM are presented in Table 4.

Table 4. Statistics derived from the difference between AT calculated elevations and the WisDOT DTM elevations.

	WisDOT AT Values	Leica AT Values
	20 Pts	20 Pts
Ave. Difference (m)	0.00	-0.09
Variance (m)	0.01	0.05
S.D. (m)	0.09	0.23
RMS (m)	0.09	0.21

The values in Table 4 indicate that both the WisDOT AT and the Leica AT elevations match very well with the WisDOT DTM elevations. The two eliminated points, 73 and 78, are included in Table 4.

The statistics presented in Tables 3 and 4 demonstrate that the WisDOT DTM corresponds more closely than the Leica DEM to both sets of AT derived ground coordinates.

4. DISCUSSION AND CONCLUSIONS

The results of this study indicate that the Leica DPW 770 softcopy system can provide AT results that are comparable to the conventional approach.

As has been reported in the literature that accuracy of automated surface generation can be substantially improved by manual editing (Mikhail, 1992). The Leica Helava DPW 770 allows the operator to select different collection strategies within their automated DEM collection routines (Miller and DeVenecia, 1992). Leica made use of this feature during the generation of the DEM files for this investigation. It is possible that the areas with different collection strategies were not matched properly when mosaiced together. Leica personnel did not have the time to examine the DEM produced by the system. If an operator visually examined the DEM generated by the automated process, the discrepancies would most likely have been detected. There are ample tools included in the Leica-Helava softcopy system to correct these errors.

5. ACKNOWLEDGMENT

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6. REFERENCES

Mikhail, E. M., 1992. "Quality of Photogrammetric Products from Digitized Frame Photography," International Archives of Photogrammetry and Remote Sensing, Vol. 29, Part B2, Commission II, Washington, D.C, pp. 390-396.

Miller, S. and K. De Venecia, 1992. Automatic Elevation Extraction and the Digital Photogrammetric Workstation, Proceedings of the ASPRS/ACSM Annual Convention, Vol. 1, Albuquerque, Mexico, pp. 572-580.