EXPERIMENTAL STUDY OF OPTIMAL DIGITAL MAPPING PARAMETERS

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ABSTRACT

The paper evaluates optimal performance parameters for digital photogrammetric mapping. This mapping method is a relatively new technique and the relationship between input parameters (flying height, pixel size and compression method) and quality of results is as yet insufficiently known. The present paper documents a statistical evaluation of this relationship. The tests with the VirtuoZo digital photogrammetry system demonstrated spot height accuracies of 1 pixel for pixel sizes up to 25 microns and 0.3 to 0.5 pixel for larger pixel sizes. The effect of JPEG compression for up to a factor 8 was insignificant.

KURZFASSUNG

Fuer Digitale Photogrammetrie wird der Zusammenhang zwischen Eingabe Parametern (wie Flughoehe, Pixelgroesse und Kompressionsmethode) und der Genauigkeit des Resultates untersucht. Zu diesem Zweck wurde ein Test Feld in unterschiedlicher Flug Hoehe ueberflogen und die Photo Bloecke mit dem digitalen System VirtuoZo ausgearbeitet. Es zeigte sich dass die Hoehen Genauigkeit fuer Pixelgroessen bis zu 25 Mikron gleich zu 1 Pixel ist, und fuer groessere Pixelgroessen gleich zu 0.3 - 0.5 Pixel. JPEG Kompression bis zu einem Faktor 8 hatte keinen merkbaren Genauigkeitseinfluss.

1. INTRODUCTION

The use of aerial stereo photography for cartographic map production is an accepted standard. During the last decennium, digital photogrammetric mapping was introduced, which uses digital images, fully automated 3-D shell reconstruction from the stereo images and automated derivation of Digital Elevation Models (DEM) and contour maps. The following parameters have to be chosen in the execution of the process, which strongly affect both the quality and costs of the product:

- Flying height/image scale, at which the serial photography is captured: The lower one flies, the more photographs are required to cover an area and thus the cost increases, but objects are visible in greater detail;
- Pixel size of the digital image: The smaller the pixel size in the digital scanner used for scanning the images, the more expensive is the scanner, and the larger is the recorded data set, but the details are more accurately recorded;
- Compression method and ratio: With less compression, large data sets remain which are costly to handle, but accuracy is preserved.

We are especially interested in the performance of these parameters in connection with **VirtuoZo,** the Digital Photogrammetry System developed at Wuhan Technical University of Surveying and Mapping (WTUSM) with some contributions from Queensland University of Technology (QUT) and marketed through VirtuoZo Systems Pty. Ltd. (Zhang, 1995). These parameters should be chosen in such a manner that the map is produced economically and to specifications. Currently, these parameters are chosen empirically, and inefficiencies exist by using high resolution scanners while subsequently applying lossy compression, where the same end result could probably be achieved with cheaper low-resolution scans and lossless compression of the image. Lossy compression results in pixel values of the reconstructed image which may differ from the original ones (Wallace, 1991). The relationships in choosing these parameters are currently not well understood, and experimental work was required in order to guide our further theoretical studies. In particular, image compression is required in the production environment, as one single digital image may already occupy some 400 Mbytes and several hundred images may be necessary within one mapping project. The compression should however not counteract costly accuracy gains, which were obtained by using high resolution scans and at low altitudes.

The experiments were done on equipment available at the Centre, such as the **Helava** or the **VirtuoZo** digital photogrammetric systems. The data sets for the experiments were aerial photography of a test field of appr. 4km*4km at Queenslands Department of Primary Industry's (QDPI) Gayndah site in Central Queensland. The terrain at this test site can be described as flat to rolling pasture land, with height variations up to 20 metres. Tufted grass 20 cm tall was abundant. A narrow water course with some steeply eroded areas and stands of trees traversed the area. Image 1 shows a 3-D view of a representative section of the test area, which was

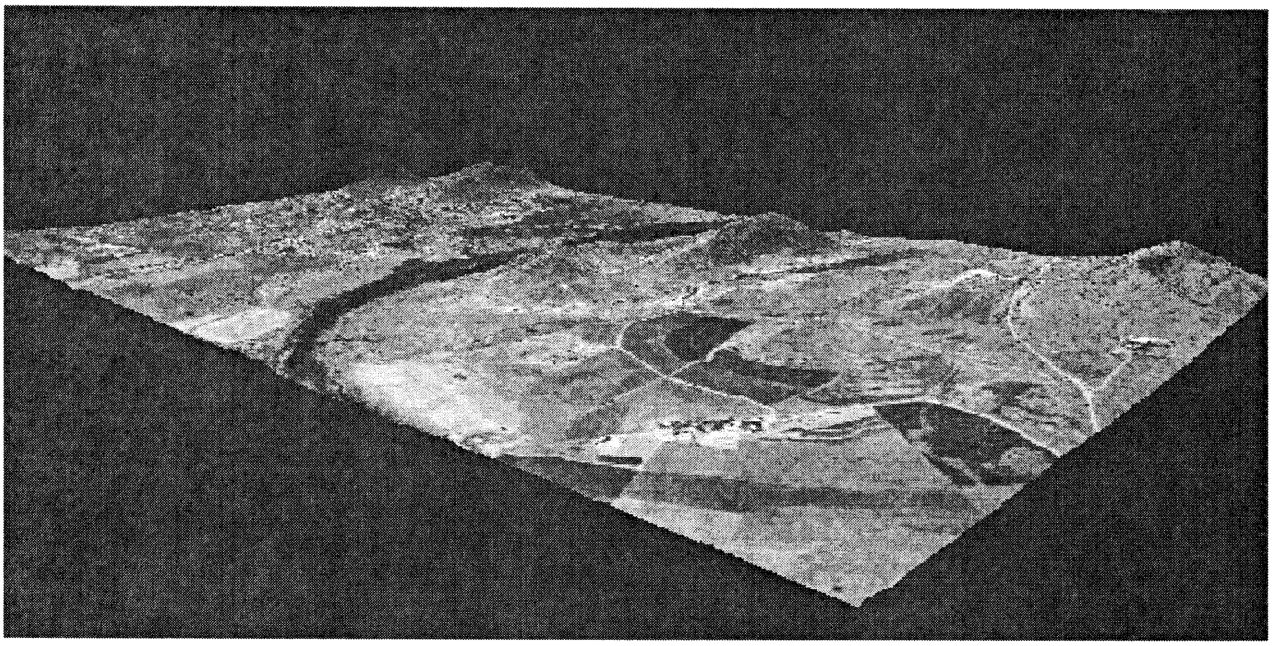

Image 1: 3-D view of part of test area

made with **VirtuoZo's** Drape function after a seamless ortho map and DEM was derived (Kubik, 1993). To the North-West some steeper hills were covered with light forest. The test area was covered by wide angle aerial photography at five different flying heights (image scales 1:1600, 1:5000, 10 000, 25 000 and 50 000; flying heights 245m, 760m, 1520m, 3800m and 7600m resp.). High resolution analogue photography was used, which can be digitised at different pixel resolution in order to simulate different digital camera types. Both black&white and colour photography was available. Ground control and a selected number of check points were measured by Differential GPS techniques. Accuracy evaluations within the tests were, however, usually made relative to the most accurate photogrammetric restitution (1:1600) in order to eliminate outside error sources. A joint block adjustment was performed in order to establish homogeneous orientation parameters for each photogrammetric model. The individual tests within the continuing project include Traditional vs. Softcopy Photogrammetry, Accuracy vs. Photoscale, Accuracy vs. Scan Resolution, and Accuracy vs. Compression ratio (Cock, 1995).This work was done under contract to QDPI.

2. TRADITIONAL PHOTOGRAMMETRY VERSUS DIGITAL PHOTOGRAMMETRY

These tests have been done on the largest scale (1:1600) photography with a flying height of 245m above the terrain, in order to assess the potential accuracy performance of soft copy photogrammetry. A traditional Digital Elevation Model (DTM) with regular 10 m grid was collected for one stereo model using our ZEISS PLANICOMP C100 Analytical Stereo Plotter. Grid points falling on obscured ground under trees were omitted, leaving over 500 points for use. No other editing apart from an automatic blunder elimination process within the DEM comparison programme was performed. The measurements were repeated on the ZEISS C100 over the same area in order to assess the repeatability of measurements. A RMS value of 0.034m (21 micron) was computed for the differences between the two height models.

The film dia-positives were now scanned in a high quality **Helava DSW 100** at a resolution of 25 micron pixel size. Using the same controls for absolute orientation , a 10 m DEM was created over the same grid of points by soft copy photogrammetry on our **Helava DSW 750**. The differences between the original C100 DEM and the Softcopy DEM have an RMS value of 0.21m. This is very large indeed, but closer inspection learned that a systematic bias was present of 0.18m, reducing the random component to 0.11m . This 18cm bias in height can - in our opinion - be attributed to the tufted grass and crop stubble which covered most of the area. The experienced operator pushed the floating mark into the terrain to define the true ground whereas the automatic correlation was done on the top of the tufts. This experiment taught us that it is difficult to make meaningful comparisons between analytical and digital photogrammetry as some of the basic operational assumptions are different and thus hard to compare.

3. ACCURACY VERSUS PHOTO SCALE AND PIXEL SIZE

For the purpose of this test the stereo image pairs were digitised, which cover a terrain area of 1*4 km from four different flying heights (1:5000 to 1:50 000). The images were digitised at pixel sizes of 12.5, 25, 50 and 100 micron. The **Helava DWS 100** was used for the high resolution scans and a **HP 3C** scanner for the lower resolutions. No compression was applied.

Size/m	Type	Pixel/m	Mbyte	Points	match%	Elapse	System	Exec.
25/0.63	grey	21/13.1	80.0	94,102	99.0	25:42	30.6	1369.0
50/1.25	grey	11/13.8	20.0	94,046	96.3	8:51	8.4	497.4
50/1.25	col	11/13.8	60.0	94,853	98.3	11:04	22.4	513.4
100/2.5	grey	5/12.5	5.0	114,880	98.3	5:13	4.0	300.8
200/5.0	grey	5/25.0	1.3	28,191	99.0	1:11	1.4	67.1
400/10.0	grey	5/50.0	0.3	13,323	98.4	0:18	0.7	16.7

Table 2, **VirtuoZo** Processing Time for SG Personal Iris 4d30 work station vs Scan Resolution

where Size = pixel size in microns/size on ground in metres
Type = greyscale or colour
Pixels = Size of the matching window in pixels/size on ground
Mbytes = Size of the image files in mega bytes, minimum
Points = Total number of points matched
Mtch% = Mathematical reliability of match from VirtuoZo (not true accuracy)
Elapse = Elapsed time for matching process (min:sec)
System = System time for matching process (seconds)
Exec = Execution time for matching process (seconds)

Digital elevation models and contour maps were then derived by **VirtuoZo** for each of the resulting stereo coverages. Thus nine stereo pairs with a photo scale of 1:5000 were processed using **VirtuoZo** and joined to form a single DEM. Similarly, further DEM's from four 1:10000 pairs and two 1:25000 pairs were also processed. The project area was finally covered by a section of the 1:50000 stereo model. Absolute orientation parameters were imported and kept identical for all tests in order to eliminate that potential operator induced error source.

Processing times were recorded for the matching process in **VirtuoZo** to estimate the overhead caused by image size. Table 2 lists exemplary DEM processing times of **VirtuoZo** for one model 1:25 000, digitised at different pixel sizes.

We note that timing took place on a slow Personal Iris 4d30 workstation running at 30 Mhz, while normal production machines run in the order of 150-200 Mhz. It is interesting to note that the time change is non - linear. This is because the number of points matched is not dependant purely on the resolution but also on the number of pixels in the matching window. For this exercise we attempted to keep the size of the match window on the ground constant, however for the coarser resolutions we were unable to maintain this intention as the automatic process normally needs a minimum of 5 pixels to maintain its integrity. Absolute orientation parameters were imported for all tests in order to eliminate that potential operator induced error source of absolute orientation.

Table 3 gives the accuracy results of the DEM tests, showing the dependency of height accuracy on scan size and photo scale. The RMS value of spot height measurements is given in units of metre. Also listed are the height accuracy specifications of the Queensland Department of Primary Industries (QDPI). We note, that **VirtuoZo** spot height accuracy is in the order of 1 pixel for the small pixel sizes of 12.5 and 25 microns and 0.3 to 0.5 pixel for pixel sizes 50 microns and beyond. It degrades approximately linear with photo scale. The results appear to be less dependent on scan resolution than on photo scale. The RMS values are in the order of 1/7000 of flying height for 25 micron resolution, degrading to 1/2500 of flying height for the 50 micron scans. No significant differences were found for colour and black/white photography. Based on the results available, we can conservatively estimate **VirtuoZo's** DEM accuracy to be in the order of 1 pixel size. As a word of caution we again point out that absolute orientation parameters were imported for all tests in order to eliminate that potential operator induced error source.

4. COMPRESSION TESTS

The 1:1600 images were further used to study the effect of JPEG compression (pixel size 25 micron). Orientation parameters were again imported in order to eliminate the orientation errors. Lossy compression was used with quality factors of 75 and 60. For one single image, the file size through this compression reduced from 81.8 Mb to 13.5 Mb and 10.6 Mb respectively. The resulting DEM's showed differences of RMS 0.002m and 0.003m resp. against the uncompressed processing. This corresponds to 1 to 2 microns of accuracy loss and can readily be tolerated.

Further compression according to the standard JPEG format created artefacts such as blockiness in the image which was regarded as unacceptable from a cartographic point of view, for the task of producing ortho photo maps. This blockiness is a clearly visible square block structure with noticeable different average grey levels in adjacent blocks (Wallace, 1991).

Pixel Size	Scan Size	Photo Scale			
		1:5 000	1:10 000	1:25 000	1:50 000
12.5 micron	320 / 960 Mb	0.09	0.18	0.46	0.92
25 micron	80 / 240 Mb	0.11	0.22	0.51	1.09
50 micron	20 / 60 Mb	0.13	0.26	0.61	1.28
100 micron	4 / 12 Mb	0.15	0.30	087	2.50
Spot height accuracy specification of QDPI		0.15	0.30	0.76	1.52

Table 3: **VituoZo** Digital Elevation Model accuracy for different photoscales and pixel sizes

5. CONCLUSIONS

The findings of the previous tests can be combined to find allowable combinations of flying height, pixel size and compression ratios which meet the map specifications. The results will be used by the authors for further theoretical studies to explain the observed relationships and to derive compression methods which are more suited than those used in this study.

6. REFERENCES

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