IMAGE SCANNING RESOLUTION AND SURFACE ACCURACY; EXPERIMENTAL RESULTS

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ABSTRACT

In this paper, experiments show that within specific limits, there is slowly varying relation between the scanning resolution and the accuracy of surface extracted using automated matching methods. Experiments were conducted on same images scanned with increasingly higher resolutions. The surface was generated using the automated extraction techniques, and certain points were compared to high accuracy checkpoints. The resulting accuracy of the generated data was analyzed. It is demonstrated that scanning resolution has limited impact on surface accuracy.

1 INTRODUCTION

A key factor in softcopy photogrammetric production throughput is the vast volume of image data. It is a problem hindering softcopy technology from realizing its full potential. The file size of a scanned standard aerial photograph ranges between tens of megabytes to more than a gigabyte. The actual size depends on the resolution and scanning mode, i.e., panchromatic versus color. In a production environment, where hundreds of stereo models are processed, the vast quantities of digital data can easily saturate any mass storage system regardless of its size. The scale of output mapping, the required detail level of extracted information, and the target accuracy, all are factors in specifying the scale of photographic coverage. Scanning resolution is also defined accordingly. In practice, when accuracy is a priority, photographic coverage is usually scanned with high resolution. Be that as it may, there is no clear evidence that the elevation and positional accuracies are strongly affected by the resolution of the image (Mikhail, 1992). The relation between the accuracy of surface and the scanning resolution is analyzed in this paper through extensive experimental work.

2 BACKGROUND

Light (1999) examined the elevation accuracy expected in softcopy system based in the C-factor used earlier with analytical plotters. His formulation involved resolution as a factor in the theoretical derivation. In this paper, we deal with accuracy as an input starting point. Surface accuracy is usually defined by specifications of the mapping project. Accuracy in parallax measurements is calculated accordingly. The dimension of smallest feature is translated into accuracy of parallax measurement of corresponding objects. The relation between surface accuracy and parallax accuracy is defined by the base-to-height ratio as follows:

$$\frac{\Delta \mathbf{Z}}{\Delta \mathbf{P}} = \frac{\mathbf{H}}{\mathbf{B}} \quad . \qquad (1)$$

Reducing $\Delta \mathbf{P}$ to photo scale results in $\Delta\rho(\mathbf{H}/\mathbf{f})$, hence

$$\Delta \mathbf{Z} = \Delta\rho * \frac{\mathbf{H}}{\mathbf{f}} * \frac{\mathbf{H}}{\mathbf{B}} \quad . \qquad (2)$$

Theoretically, parallax measurement accuracy $\Delta\rho$ consists primarily of the accuracy in matching corresponding features. It has been shown (Ackermann, 1996) that least squares matching (LSM) can attain sub-pixel accuracy, approximately 0.3 … 0.4 of a pixel. In practice, however, $\Delta\rho$ is somewhat larger than matching accuracy alone, as other factors may affect the accuracy of parallax measurement. This error, named herein $\mathbf{p}$, represents the algebraic proportional sum of all potential errors. It follows that the $\Delta\rho$ can be expressed in pixel units, or $\Delta\rho = \mathbf{p}\,\boldsymbol{R}$, and:

$$\Delta \mathbf{Z} = \mathbf{p}\,\boldsymbol{R} * \frac{\mathbf{H}}{\mathbf{f}} * \frac{\mathbf{H}}{\mathbf{B}} \qquad . \qquad (3)$$

The latter equation shows that the surface accuracy is determined by several factors, some of which are constant for a particular coverage. Equation (3) shows that the expected surface accuracy $\Delta \mathbf{Z}$ is about 0.11 meter if $\mathbf{p}$ is 0.3 of a 28 μm resolution $\boldsymbol{R}$, a base-to-height ratio $\mathbf{B/H}$ is 0.6, the focal length $\mathbf{f}$ is 151.6 mm, and the flying height above ground $\mathbf{H}$ is 760 meter. Most of these variables are often consistent for a specific mapping project. However, if the ratio $\mathbf{p}$ is relaxed to a practical value of 0.6 of a pixel unit while the other variables remain the same, then $\Delta \mathbf{Z}$ is degraded to 0.22 meter. These values closely reflect the conditions under which the experiments were conducted. Applying equation (3) on various values of scanning resolutions $\boldsymbol{R}$ yields the theoretical values of surface accuracy if the surface is extracted using automatic matching techniques. These values are presented in Figure 1. In this figure, it is shown that the degradation of accuracy is strongly correlated to resolution, as it is the only changing variable in the equation.

The surface accuracy is often expressed in terms of a ratio of the flying height, i.e., $\Delta \mathbf{Z}/\mathbf{H}$, such as 1/10,000 or 1/5,000. This ratio is defined in the mapping specifications, depending on the terrain, purpose of the project, and the quality of photographic coverage.

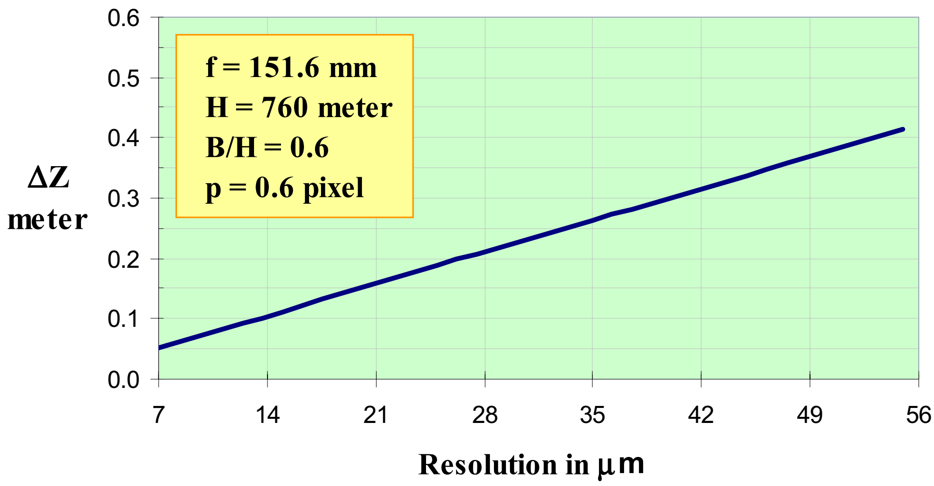

Figure 1. Theoretical Values of $\Delta \mathbf{Z}$ for Generated Surface at Various Resolutions

With little modification of equation (3), this accuracy ratio can be calculated as follows:

$$\frac{\Delta \mathbf{Z}}{\mathbf{H}} = \frac{\mathbf{p}\,\boldsymbol{R}}{\mathbf{f}} * \frac{\mathbf{H}}{\mathbf{B}} \qquad . \qquad (4)$$

The resulting $\Delta \mathbf{Z}/\mathbf{H}$ ratios for the two earlier examples are 1/7,400 and 1/3,700 respectively. These values are highly influenced by the 0.6 base-to-height ratio. The same range of scanning resolutions $\boldsymbol{R}$ used in Figure 1 is applied with equation (4) to determine the corresponding $\Delta \mathbf{Z}/\mathbf{H}$. Figures 2 depicts, on theoretical basis, the expected accuracy to height ratio calculated using various scanning resolutions. The reciprocal of $\Delta \mathbf{Z}/\mathbf{H}$ is used instead, however, because it conveys an immediate understanding. The figure shows a sharply declining accuracy (numerically larger) ratio from higher than 1/14,000 in the 7 μm area down to about 1/2,000 with 56 μm. More specifically, a rapid degeneration of accuracy ratio occurs at fine resolutions, while at coarser resolutions the ratio flattens.

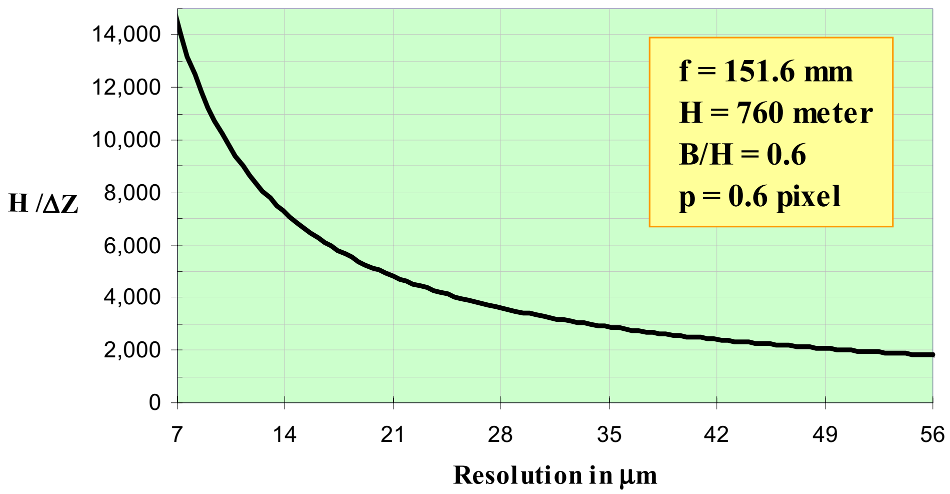

Figure 2. Theoretical Values of $H/\Delta Z$ Based on Various Resolutions.

3 EXPERIMENTS

A segment of a block was selected based on specific criteria. These include adequate terrain variations, least tree covers, and substantial ground features. We used the SCAI system by Zeiss to scan the photographs with different resolutions. Description of the data sets is summarized in Table 1. The interior orientation was conducted on all images individually. Exterior orientation, on the other hand, was only conducted on the finest resolution images, i.e., 7 µm. The exterior orientation parameters were then transferred to the same images at the other resolutions.

Each pair was then rectified to generate epipolar images. Automated matching techniques, based on LSM, were applied on the epipolar images for surface extraction. The resulting output surface data (unedited) were compared to the same check points, except where blunders were detected. The accuracy of the surface was then assessed in view of the scanning resolution. Results are summarized in Table 2.

Photography	Color Infra-Red
Flying Height	760 meters
Overlap	80%, successive
Base-to-height	0.3 and 0.6
Focal Length	151.644 mm
Scanning Resolutions	7, 14, 28, 56 µm
Scanning Modes	7: Panchromatic 14, 28, 56: Color (RGB)
Processing Modes	Panchromatic, Principal Component
Total # Check Points	47

Table 1. Description of Data Sets

Resolution (µm)	RMS in Meters	
	B/H = 0.3	B/H = 0.6
7	0.154	0.113
14	0.212	0.123
28	0.250	0.128
56	0.379	0.249

Table 2. Summary of Experimental Results

The surface accuracy is presented in Figure 3 along with the earlier calculated theoretical results. According to the figure, the experiments show that coarser scanning resolution would result in degrading accuracy values in a much slower rate than the theoretical expectations. The experimental results at finer resolutions show that more realistic accuracy can be attained with the typical 0.6 base-to-height ratio. At around 14 µm, the theoretical and experimental values are close to each other. The behavior at coarser resolutions is of particular interest. The experiments show that far less degradation in accuracy occurs in coarser resolutions than expected. The figure shows that surface is very weakly correlated to the resolution. The experiments thus demonstrate that far less degradation in accuracy occurs in coarser resolutions than expected.

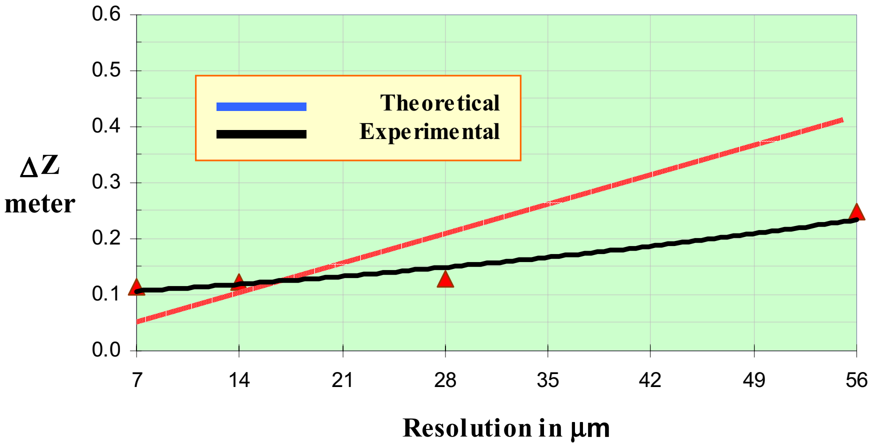

Figure 3. Experimental values of ΔZ compared to theoretical values

4 CONCLUSIONS

In this paper, results are reported for extensive experiments to examine the relation between surface accuracy and scanning resolution. We used 7, 14, 28, and 56 µm resolutions. The surface was generated using automated extraction techniques based on LSM matching methods. Surface points were compared to accurate check points and the differences were analyzed. The results are expressed in direct RMS errors, as well as a ratio of the flying height. These results show that there was far less degradation in accuracy as a direct result to increasing (coarser) resolution. These experiments demonstrate that although there was a reduction in accuracy, this reduction is significantly slower than expected. This finding strongly indicates that scanning resolution is not a primary factor in surface accuracy.

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