

The Effect of Scanning Resolution in Digital Photogrammetric Workstation

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Abstract: Pixel resolution is one of the main factors that affecting the final result in digital photogrammetry in general and in digital photogrammetric workstation in particular. An aerial wide-angle hard copy stereo pair was transformed to a soft copy using different scanning resolution by special photogrammetric scanner. Digital photogrammetric workstation was used to measure a number of control points of a known ground coordinates. ERDAS package was used to digitally rectify the scanned images using the same pixel resolution used above. And the coordinates of points were measured again. The results of this investigations proof that the accuracy of the measurements in digital photogrammetry is proportional to scanning pixel resolution in both horizontal and vertical measurements. And mathematical models were developed to estimate the accuracy via scanning resolution and suitable plotting scale in both horizontal and vertical mapping. Production of maps using digital image rectification using software packages such as ERDAS is suitable only in flat terrain. And digital photogrammetric workstation is a productive way for mapping in all flat and mountainous terrain.

Key words: Digital photogrammetric, pixel resolution, planimetric, scanning

INTRODUCTION

Photogrammetry is one branch in surveying that largely been affected by the development in computer technology in data acquisition, image development and processing, adjustment and further in mapping of data (Mikhail, 1993).

Various subjects relevant to the process of digital mapping become important (Russ, 1995).

These subjects may include digital camera, which represent the alternative instrument of conventional camera and by which direct digital data can be acquired (Wong, 1980). Photogrammetric scanners which are made precisely to transform hard copy images into digital form (Jensen, 1986). Digital image processing software's that; solve the problem of spending along time in photo-laps. Digital photogrammetric workstation is one of the yields of developments in photogrammetry, which is replacing gradually analogue and analytical plotters (Methley, 1987).

MATERIALS AND METHODS

This study tries to investigate the effect of scanning resolution on the accuracy of the end results of the measurements taken with digital photogrammetric

workstation in particular and in rectified digital images as one method of digital mapping now a day (Janssen, 2000).

First, transform the aerial wide-angle hard copy stereo pair of the study area to a soft copy using different scanning resolution by special photogrammetric scanner.

Then, digital photogrammetric workstation has to be used to measure a number of control points of a known ground coordinates.

The root mean square error of the measured ground coordinates of points and their actual coordinates should be computed for each scanning resolution.

Digitally rectify the scanned images using the same pixel resolution used above by ERDAS package. And the coordinates of points have to be measured and the root mean square errors computed a gain.

Suitable horizontal and vertical scale for each scanning resolution is to be investigated and mathematical models developed for both digital photogrammetric workstation and digital rectification (Paul *et al.*, 2000).

Study area: The aerial stereo pair consists of two successive 60% overlapping vertical photographs taken in mountainous terrain in Switzerland with a Wild RC10 universal film camera wide angle of 152.77 mm focal length, 230×230 mm format, 6010 m flying height was used in this study.

RESULTS AND DISCUSSION

Ultra scan 5000 was used for scanning the stereomodel with different resolutions (Gonzalez *et al.*, 1993). These were selected to be 10, 20, 30 and 80 μm. This transform the hard copy images into a soft copy in a digital form to take memory as shown in Table 1.

Now, if a graph is plotted for the pixel resolution (Town Shend, 1992) used to scan a hard copy of an image via the memory size required for the resultant digital image as shown in Fig. 1. A mathematical model can be created to estimate the memory size by the following exponential equation:

$$y = 170548x^{-2.0017} \tag{1}$$

Where,

- y : Is the estimated memory size,
- x : Is the required pixel size.

Results of DPW measurements: After completing inner and relative orientation of the digital model using Digital Photogrammetric Workstation (DPW), absolute orientation was carried out using the control points (Wolf, 1985). Then the curser was located at each checkpoint and its coordinates was read out. This process was carried out for each scanning resolution.

In this research, the accuracy estimation based on the criteria of the root mean square error RMSE Eq. 2

$$RMSE = \sqrt{\frac{\sum(\bar{x} - x)^2}{n}}$$

Where,

- \bar{x} : Is the actual quantity,
- x : Is the measured quantity and
- n : Is the number of quantities.

The root mean square errors of the measured coordinates of points were computed for each scanning resolution and tabulated in Table 2.

It can be seen from the table that the RMSE of X was computed to be 0.43, 0.55, 1.50 and 2.32 for the resolution of 10, 20, 30 and 80 μm, respectively.

A graph plot of pixel size via accuracy obtained in X-coordinate Fig. 2 demonstrates that slight change in accuracy is occurred up to 20 μm. But from 20 up to 80 μm quicker change is noted.

The RMSE of y-coordinates was computed to be 0.57, 1.05, 1.92 and 2.59 m for 10, 20, 30, 80 μm pixel size, respectively. Again by studying Fig. 3 it can be seen that the rapid declination in accuracy of the measured Y-coordinate for the pixel size grater than 20 μm.

Table 1: Memory size of digital images

Pixel size	Memory size (Mb)		
	Left image	Right image	Mean
10	623.2	10	623.2
20	429.0	20	429.0
30	192.0	30	192.0
80	26.8	80	26.8

Table 2: Estimated accuracy

Resolution	RMSE				
	X	Y	Z	XY	XYZ
10	0.43	10	0.43	10	0.43
20	0.55	20	0.55	20	0.55
30	1.50	30	1.50	30	1.50
80	2.32	80	2.32	80	2.32

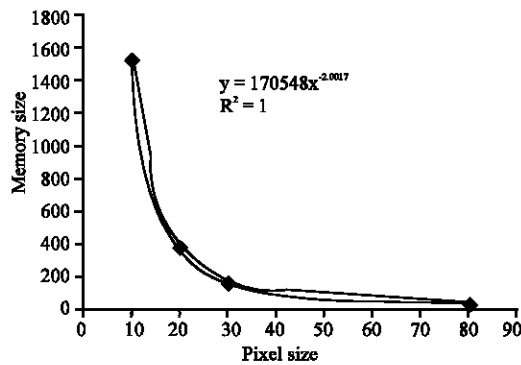


Fig. 1: Pixel resolution via memory size

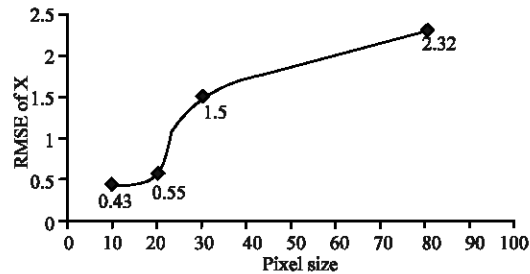


Fig. 2: Accuracy of X-coordinates

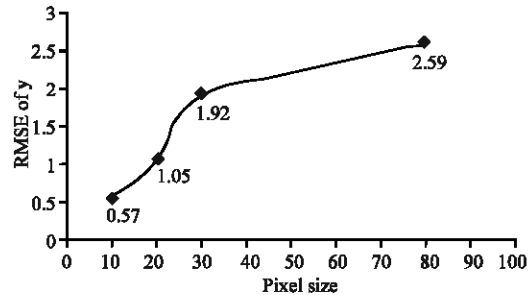


Fig. 3: Accuracy of Y-coordinates

By studying Fig. 4 which represent the pixel size via RMSE of Z-coordinate, it can be seen that the accuracy

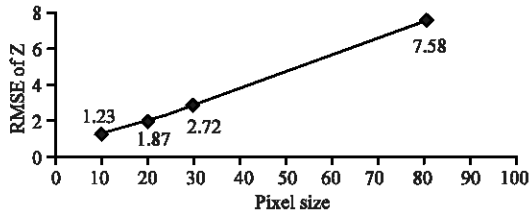


Fig. 4: Accuracy of Z-coordinates

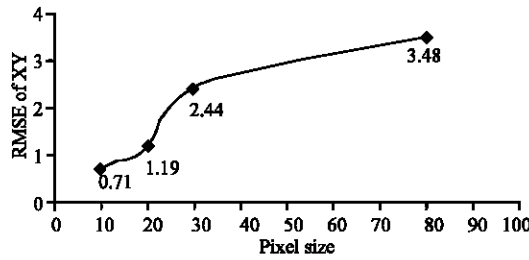


Fig. 5: Planimetric accuracy

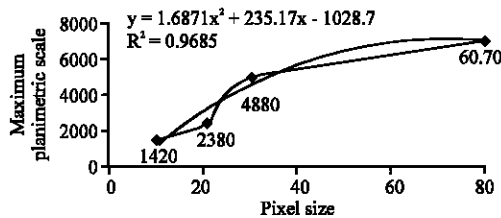


Fig. 6: Maximum estimated planimetric scale

is quickly (linearly) reduced with the increase of pixel size compared with that obtained for X and Y-measured coordinates and this may be due to the fact that the intersection of height is sensitive specially in steeper ground (Ali, 1992). On other hand, the planimetric accuracy, which is important for mapping purposes, was found to be 0.71, 1.19, 2.44 and 3.48 facing the pixel size of 10, 20, 30 and 80 μm , respectively Fig. 5.

By assuming that the measurement on the map conventionally can be taken up to 0.5 mm, the suitable maximum horizontal and vertical scales can be computed for each scanning resolution depending on the accuracy obtained above.

The maximum planimetric scale for each pixel size is computed as shown in Table 3.

A graph in Fig. 6 is a plot of planimetric accuracy via scanning resolution. From which Eq. 3 can be derived to estimate the maximum planimetric scale to the pixel resolution as follows:

$$y = -1.6364x^2 + 230x - 909.09 \quad (3)$$

Table 3: Maximum planimetric scales

Resolution	Suitable planimetric scale
10	1:1500
20	1: 2400
30	1:4900
80	1:7000

Table 4: Maximum vertical scale

Resolution	Suitable vertical scale
10	1:2500
20	1:3800
30	1:5500
80	1:15200

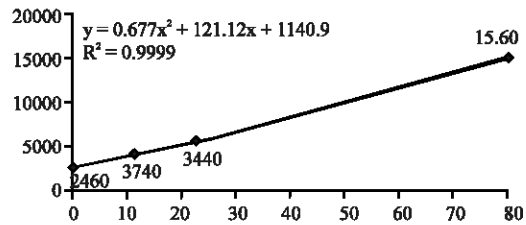


Fig. 7: Pixel size via maximum vertical scale

Where,

- y : Is the maximum estimated planimetric scale,
- x : Is pixel size.

Now, from Z-coordinate accuracy obtained from the results above, a maximum vertical scale is computed as shown in Table 4.

A graph in Fig. 7 is plotted to fit the maximum vertical scale by the following polynomial equation:

$$y = 0.6554x^2 + 123.02x + 1166.2 \quad (4)$$

Where,

- y : Is maximum vertical scale and
- x : Is the pixel resolution.

Erdas Imagine 8.5 package was used for producing a rectified digital image of the study area. The accuracy of the measured X and Y- horizontal coordinates was tested using this software against the pixel resolution.

Four control points were used to rectify the digital image of the study area using first order polynomial. Table 5 demonstrates the standard error obtained for the measured coordinates of points for each scanning resolution.

From inspection of the above three results obtained from digital rectified image it can be seen that the accuracy is very low even in the image of 20 μm pixel resolution. This is due to the relief displacement.

Table 5: Accuracy of rectified images

Resolution	RMSE(m)		
	X	Y	XY
10			
20	13.34	20	13.34
30	13.38	30	13.38
80	13.79	80	13.79

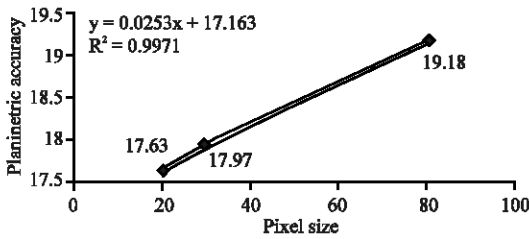


Fig. 8: Accuracy of rectified image via pixel resolution

Remember that this error is proportional to the measured point (Kilford, 1973) and that the study area is of mountainous nature. Table 5 represents the accuracy of the rectified images estimated by the root mean square error.

Analyzing the results in Table 5 it can be seen that increasing the pixel resolution slightly improves the accuracy of the measure rectified image coordinates. This is due to the fact that the measurements are taken from a single image. Figure 8 represents the planimetric accuracy of the rectified image and its pixel resolution (Novak, 1992). From this graph, it can be said that the planimetric accuracy of a rectified digital image is proportional linearly to the pixel size by equation.

CONCLUSION

By referring to the all results of measurements taken from the models created from different scanning resolution using DPW. And by referring to the results of the ERDAS investigation measurements carried out in this research, one can conclude the following:

- Increasing the image resolution directly increase digital image size; therefore, digital photogrammetric projects need large data storage such as USB of 80GB memory size or more, which is now available besides the easy-travelers that assist to use an external hard disk. And from the results in this study it can be said that memory size can be estimated for the Utrascan 5000 scanner by the equation:

$$Y = 170548x^{-2.0017}$$

Where,

- y : Is the estimated memory size.
- x : Is the required pixel size.

- Due to the large amount of data to be processed, sufficient RAM should be available. Therefore, it was found to be that slow roaming is obtained with increase of image resolution.
- Resampling of rectified image delay with the increase of memory size i.e. take a long time. Efficient processor is needed in digital photogrammetry.
- The relation between the pixel size and the accuracy is nonlinear.
- Scanning the photographic images with resolution of 10 µm pixel size is suitable for all photogrammetric works including aerial triangulation and digital elevation modeling since the triangulation points can easily be identified. And it can be used to develop planimetric maps of 1:1500 scale or smaller. This resolution can be used in contouring large-scale topographic maps to produce maps of 1:2500 scales or smaller.
- Images can be scanned with pixel size of 20 µm if planimetric maps of scale 1:2400 and smaller or contour maps and profiles of vertical scale of 1:3800 or smaller are to be derived. This pixel size is also suitable for aerial triangulation purposes. Since control points can be distinguished on the digital image. And it can said to be that 20 µm a compromise between accuracy and economy.
- If it's necessary for a particular project to drive planimetric maps of scale 1:4900 and contour maps of 1:5500 or smaller. It is recommended to scan the hard copy images with photogrammetric scanner applying pixel resolution of 30 µm.
- Up to 80 µm pixel size, the planimetric scale can be estimated from the pixel size by applying the following polynomial equation

$$y = -1.6364x^2 + 230x - 909.09$$

Where,

- y : Is the maximum planimetric scale
- x : Is pixel size.

- Vertical scale required for topographic mapping and contouring can be estimated from the scanning resolution by the equation:

$$y = 0.6554x^2 + 123.02x + 1166.2$$

Where,

- y : Is maximum vertical scale and
- x : Is the pixel resolution.

- Planimetric accuracy of a rectified digital image is proportional linearly to the pixel size.
- It is not suitable to take measurement from a rectified single image of a mountainous nature.

- Increasing the pixel resolution slightly improve the accuracy of the taken measurement from a single rectified image about 2.5%.
- In flat terrain such as Khartoum, digital rectified image of 1:20,000 scale and 20 μm resolution can be used to produce maps of 1:6600 scales or smaller. 14.80 μm pixel size used for scanning the photographic images distort small features. Therefore, it is difficult to identify the control points used for orienting digital images.
- Resolution can produce planimetric accuracy of 3.48 m, which can be used to derive planimetric map of 1:6900. The same resolution can produce vertical accuracy of 7.58 m that can produce maps of 1:15000 vertical scales or smaller.

Finally, it has to be mentioned that the aerial stereopair available for the research was small scale, 1:40,000 rather using medium or large-scale photography which may produce a better results than theses obtained, (since the planimetric accuracy of derived X, Y coordinates is directly proportional to the image scale and height error is proportional to object the object distance i.e. flying height above ground).

Also, the study area was of mountainous nature. And the height of points various between 817 and 1085 m, by difference of 268 m. The steep slops of the area may affect the accuracy of the measurements. But flat terrain provides ease of measurement and good results.

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