Photogrammetric Precision of a Desktop Scanner

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Abstract

Scanners are used to convert analogue photography into digital format. High quality and precision photogrammetric scanners are not easily reachable due to their high cost. This paper investigates a new strategy to test a sample low cost desktop scanner to estimate the achievable precision of the product. The digitization quality of the test pattern is investigated at different warm up times and different positions in the scanning area. Notes are given on the performance of the scanner in geometric and radiometric aspects that are essential for photogrammetric applications.

Keywords: Scanner, precision test, digital image.

الدقة التصويرية لجهاز السكانر

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الملخص

تستخدم أجهزة السكانر لتحويل البيانات من صور أو رسوم على الورق الى صيغة رقمية Analogue to Digital. ويصعب الحصول على الأنواع ذات الكفاءة والدقة العالية منها والتي تصلح لأعمال المسح التصويري Photogrammetric Scanners بسبب كلفتها العالية. في هذا البحث يتم تحليل احد الأنواع الشائعة والرخيصة من جهاز السكانر للتعرف على مدى الدقة الممكن الحصول عليها في الصور المنتجة. ان كفاءة عملية التحويل الرقمي لنموذج الأختبار قد تم تحليلها في مواقع مختلفة من مساحة الصورة وعلى فترات تشغيل مختلفة لملاحظة تأثير الموقع ووقت التشغيل على نتائج عملية المسح. ويقدم البحث ملاحظات حول جوانب تتعلق بالدقة الموقعية والكفاءة الضوئية وهي عناصر هامة لدقة اعمال المسح التصويري.

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Introduction

Presently, analogue photography is still a major source of air survey data. Few decades ago, it was the only available media for photographic data capture and storage. Old photogrammetric data and maps in this format is prone to various types of distortion due to bad storage, humidity, wear, and various physical and chemical effects. It is highly recommended at this stage to convert available photogrammetric data into digital format.

A photograph in digital format is composed of a matrix of digital numbers representing the intensity of light reflected from various surface materials. In this format, photographs are more suitable for computerized automated processing. Image processing tools are used for mapping more speedily as compared with traditional manual techniques (Mikhail et al. 2001). Photographs in digital formats can be stored as computer files on CDs or DVDs for unlimited periods of time. The result image quality is always identical to first ever copy produced.

The major source of digital data is that obtained directly from the imaging media such as, satellite, aerial or terrestrial digital cameras. For old and analogue photographs, scanners are used to convert data into digital formats. Photogrammetric quality scanners of highest precision are recommended if the geometry have to be preserved in the product (Bolte et al. 1996). Photogrammetric scanners are costly, usually made with high precision requirements. Electronic components, lenses and movable parts are all made for higher performance. Examples are, UltraScan5000, VX3000, RM-1 and others (Michael et al. 2000). On the other hand, desktop scanners are continuously upgraded and modified. Unlimited brands are displayed in the market with lower prices. Most are used for ordinary day to day use for scanning photographs and documents. Yet the degree of geometric precision obtained from these scanners is not well documented.

Desktop scanners are basically intended for quite different type of users than the typical photogrammetric usage. Accordingly, these types of scanners must be checked before use in photogrammetric measurements. Several important features define the level of scanner exploitation in photogrammetry (Mitrovic. Et al., 2000):

1- Scanner type (flatbed or drum),
2-The suitable scanning format.
3- Geometric resolution in dpi,
4- Radiometric resolution in bytes or bits per pixel,
5- Geometric accuracy.
6- Density range.
7- Capability of scanning transparent materials.

In order to objectively evaluate geometric accuracy it is necessary to know the most important error sources and their nature. In general, these errors can be divided into slowly and frequently varying errors.(Mitrovic. et al., 2000)
Slowly varying errors are:
1- Lens distortion
2- Misalignments of CCD sensors
3- Imperfection of transport mechanism

Frequently varying errors are:
1- Vibration
2- Electronic noises
3- Mechanical positioning

This paper introduces a method to test the attainable precision from using a sample desktop scanner usually available at lower price in the market. The author exploits the expected precision and the usable resolution that is suitable for mensurations. Mention of trade names or commercial products in this article is only for the purpose of providing specific information and does not imply any recommendation.

Materials

The sample scanner used in this investigation is the Epson Stylus CX3900. A low cost easy to use and widely available scanner of A4 paper size. (also used for printing and photocopy). Fig. (1.)

Figure (1.) The sample desktop scanner used in this work.

The major aim of this study is to investigate precision and radiometric aspects of the scanner. This requires the preparation of a reference frame of control points distributed all over the scanning area. Accordingly, detected errors (shifts in point locations) are measured and evaluated at different locations.

It is not easy to prepare a test pattern with precisely known coordinates of points (Baltsavias E. et al, 1995). A special glass plates with etched marks of well defined X,Y coordinates is not available. The author suggests generating a matrix of control points using AutoCAD program. This pattern covers the whole area of an A4 paper size, the active scanning area of the scanner under investigation. This assures evenly distributed set of points having double precision values of coordinates. Accordingly, these coordinate values are used for monitoring any shifts in point locations due to errors in successive scans to be made later. see Fig (2.)

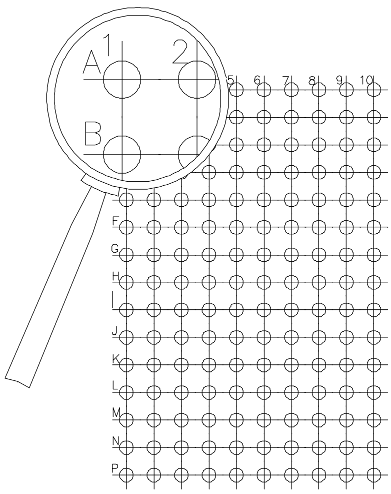


Figure (2.) The test model with enlarged view of control points A1, A2, B1.

This map of control points was printed and used later for the consecutive set of scans. The scanning process was performed immediately to assure that the paper material do not shrink or expand due to humidity, heat or bad storage. The following set of scans were performed on this sample.

1- Immediately after starting the scanner before warm up period, three consecutive scans were made on the sample with exactly the same configuration. This will be used to compare the repeatability of output (images 21, 22, 23, namely image group (21)).

2- After warm up period of approx 30 min., three more scans were performed. This is performed to observe the effect of warm up period on error in point locations (image group (27), 28, 29)

All scans were made at resolution of 600 dpi (0.042 mm /pixel) resulting in images of 5100 columns X 7019 rows. The requirement to perform higher scanning resolution was postponed according to the outcome of this study. At this stage, all images are converted into raster format.
In order to measure locations of control points on a scanned image, measurements can be performed using the human eye and computer mouse movements on enlarged views of each point. This is a manual way where human error may occur in locating fine details of points. The author suggests the use of an automated method, i.e., A raster to vector conversion program that vectorizes the scanned document. The program R2V digitizing software (Able Software, 1998) vectorizes or converts raster images into thin lines and stores the result into dxf (vector) format. In the program, vector lines follow the centerlines of thin raster paths.
In dxf format. AutoCAD program displays the result. Comparisons are made between any selected sets of measurements. In all cases, reference measurements were made relative to the control point at the lower left end of the frame (point P1 as in Fig.(2)).

Tests and Results

Due to the raster nature of the scanned pattern, lines and edges are contaminated with irregular spots affecting the degree of detail that can be observed for line and point identification as shown in Fig. (3.) Possible reasons are given below.

1- Enlargement of digital images causes individual pixels begin to appear and cause discrete pattern. This is case is normal in raster image manipulations.
2- Randomness of pixel locations can be the result of improper electronic, mechanical and optical performance of the scanner.
3- Point shifts and irregularity in locations may come from defects of the original scanned image.

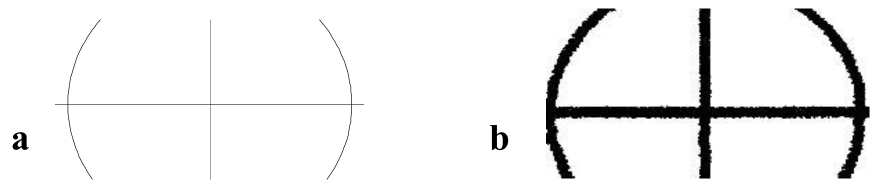


Figure (3.) A typical control point a)-In ideal vector form, and b)- after scanning.

Moreover, applying raster to vector conversion program to raster images inherits much of these defects in the output. Vectorizing the pattern shown in Fig (3b) produces the shape of the sample control point in Fig (4.) Obvious defects in the vector product make location measurements using computer mouse on points of the control pattern to be fuzzy. All shift measurements were made on this vector form of the test pattern.

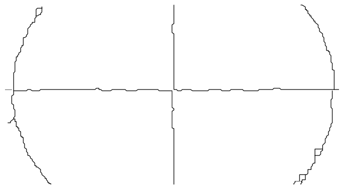
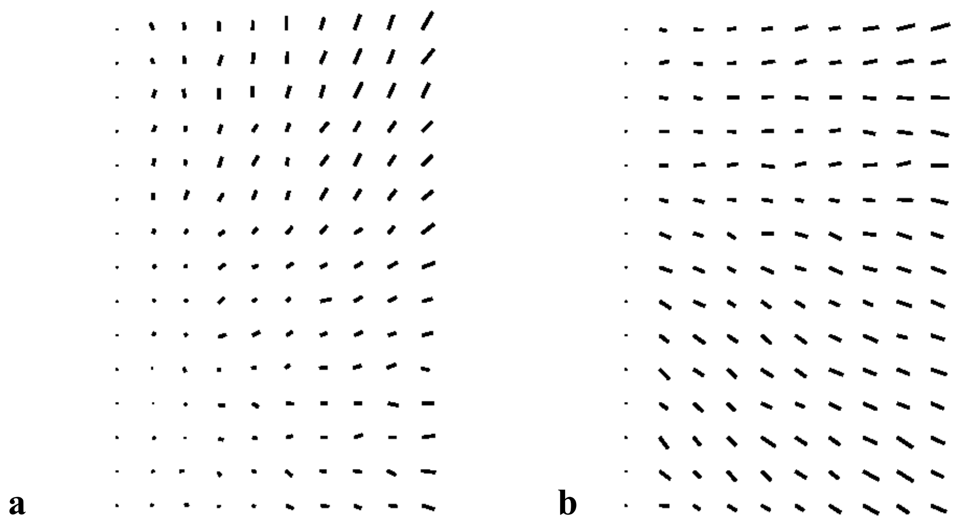


Figure (4.) Vectorized form of typical control point from Fig (3 b.)

Test results show that errors or shifts in point locations are distributed all over the scanning area. Position errors that appear early during startup period are considerably less in magnitude (Fig (5a).) as compared to results after warm up period which are shown in (Fig (5b.)). In both cases slight image change in dimensions is obvious in both row and column directions. Particular note is that the left column of control points has less amount of shifts which increases gradually towards the right and towards both sides of the central row. Visual inspection of the shift arrows shows superior quality of image group 21 (before warm up period) as compared to that of group 27 (after 30 minutes).



Figure(5) a) Shift errors in image group 21 . b) Shift errors in image group 27, magnification factor : 30

Statistical testing of the results for image group 21 for the frequency and amounts of shift is shown in the histogram and table of fig 6., with average amount of 0.243 mm. The histogram shape is approximately normal, it shows the errors of combined systematic and random components. Figure 7 shows the histogram and table for image group 27. In this case, although the average error is less (0.168 mm). The histogram shape departs from normality, skewed and have higher standard deviation.

In both cases, scale increases unevenly in both row and column directions. Table (1) shows that in image group 21, In the column direction, the scale amounts to about 1:0.9980. While in the row direction, the scale is 1:0.9992. Similarly in the second case, image group 27, In the column direction, scale is about 1:0.9989 at the extreme right. While in the row direction, the scale is 1:0.9982.

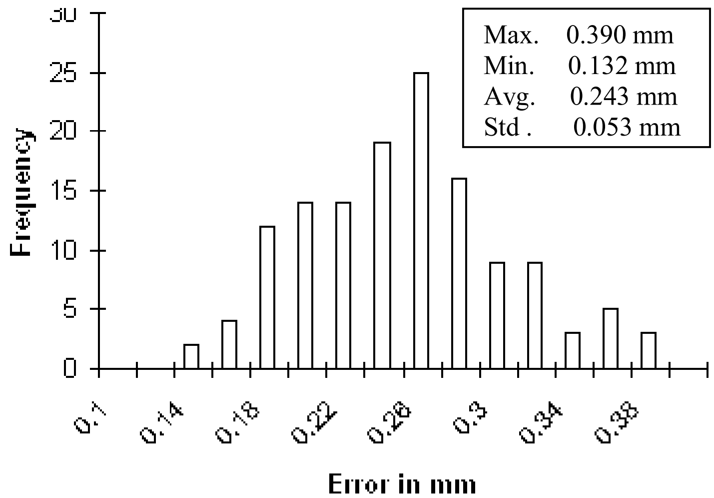


Figure (6.) Histogram of Image 21 total error in (mm)

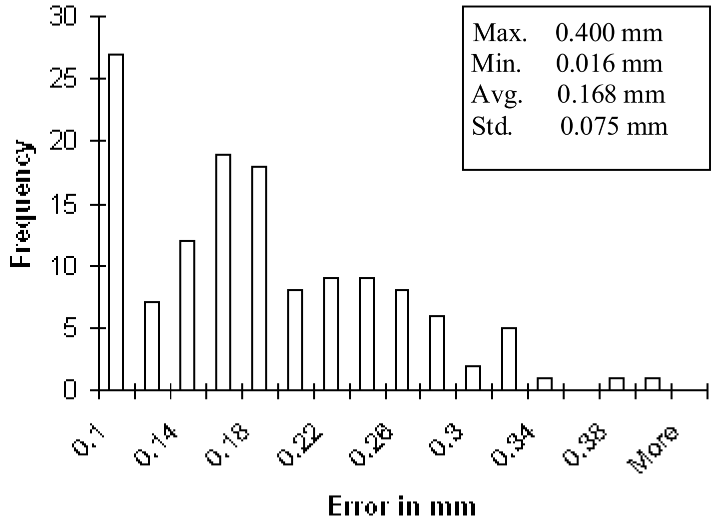


Figure (7.) Histogram of Image group 27, total error in (mm)

Table 1: Scale variations in Column, row directions.

	Row Scale	Column Scale
Image group 21	1:0.9992	1:0.9980
Image group 27	1:0.9982	1:0.9989

In theory, differencing two identical images produces an image of zero values (DN)(Gonzalez, et al 1987). In this study, the author concludes that repeated scans of the same configuration does not produce identical results. Figure 8 shows the differencing result of images 21-22 (from group 21). Shifts of points exist in both column and row directions shown as two eccentric circles. In this particular location of control point, the maximum shift amounts to about 9 pixels in the row direction (approx. 0.37 mm at 600 dpi). Less shift is seen in the column direction. This conclusion surrogates the finding stated earlier in figure 5 that shifts exist in both directions.

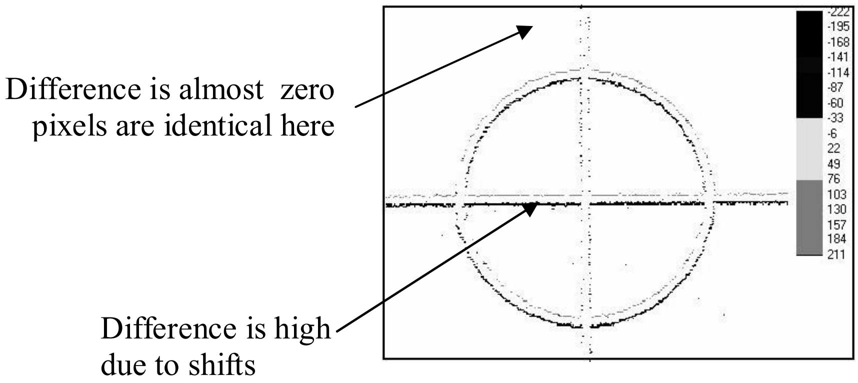


Figure (8.) Differencing images 21-22, enlarged at a typical control point.

The histogram of the difference image in figure (9) reveals that zero (and near zero) differences are more frequent. While, the range of non-zero values of differences extends from (-222 to +211 digital numbers). This conclusion is unfavorable for using the scanner for precise geometric measurements.

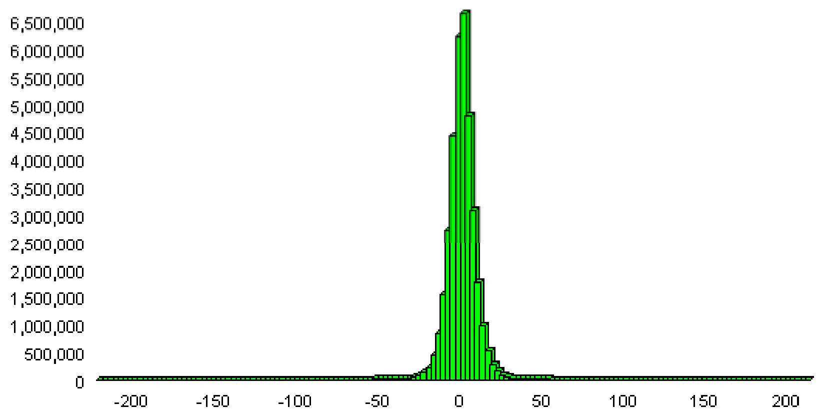


Figure (9.) Histogram of digital numbers of the difference image of figure (8.)

Conclusions

Errors in point locations are unevenly distributed across the scanning frame. Generally less errors are noticed at and near the left column of the scanned frame. The error increases gradually to the right. As the average error of shift in point location is in the order of 0.25 mm, this amount governs the type of usage of this scanner. Attempts to make high precision measurement beyond this limit shall be avoided. The amount of error after a warm up period of about 30 min. is more than that observed during the first minutes of switching on. This conclusion is controversial with the findings of others (Baltsavias E., 1999). We advise that the suitable usage of this scanner is that intended for illustrative and display purposes. As these conclusions are based on tests on a single scanner unit the author recommends similar tests on many other units to gain statistical conclusions.

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