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TECHNICAL NOTE

Geometric Effects of Enlarging Small-format Aerial Photographs with Commercial Electronic Copier

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Abstract. Small-format aerial photographs were electronically enlarged and then tested for geometric errors caused by enlarging. A Wild AC-1 analytical plotter and an Altek Data electronic digitizer were used for this purpose. Although some 23% of image area was cut off in the enlargement process, geometric deformations were relatively small. Thus average values of -1.12 mm and +0.91 mm resulted for stretch along the x-aixs and skewness respectively. These findings, coupled with the fact that electronic enlargement costs only 30% of that performed with conventional optical techniques, suggest that electronically enlarged small-format aerial photographs could serve a useful purpose in application areas where costly and highly sophisticated mensuration equipment need not be used.

Introduction

In the context of aerial photogrammetry, the standard 9" x 9" (23 cm x 23 cm) image format film has found a multitude of applications and thus remained for many years the main source of information for compilation and preparation of large and medium scale topographic maps as well as derivation of information regarding surveys related to engineering, agriculture, land use, forestry, urban planning, geology etc. using the well-established techniques of photointerpretation. In contrast, small format photography (35 mm and 70 mm) has enjoyed less popularity despite the fact that accurate metric information could be derived from it if certain photogrammetric precautions and measures are observed. One important aspect is the requirement to work with the original diapositive because of the fact that enlarging the film using conventional optical printing methods causes both scale change and reduction in image area to amounts ranging from 10% to 22% [1].

Nowadays, a new type of enlarger is being marketed worldwide. Rather than relying solely on optical projection, these emerging color laser copiers electronically scan an image, thus converting the various image densities into digital numbers which could later on be processed with a computer, and enlarged hard copies on film could again be produced. This suggests re-assessment of the use of small-format aerial photography for photogrammetric work.

Test Area, Material and Procedure

Test material used in this study consists of four 35 mm format aerial photographs taken with a Pentax camera equipped with an Echtachrome 1/400 film over an open tarmac car park approximately 200 m x 150 m in extent. White line crosses (forming the parking bays) on the car park constituted test targets that needed to be measured on the photos. A total of 300 targets were celarly identified. No attempt was made to interpolate the positions of rubbed out crosses. They were simply ignored.

Initially, the unenlarged positive transparencies were placed in a Wild AC-1 analytical plotter running under the command of a Data General NOVA/4 host computer. The plotter has a point location accuracy of around ±1 μm. An operator of several years experience in operating the AC-1 carried out the measurements of the test targets. Every effort was made to place the floating mark exactly on the center of cross target in an attempt to minimize pointing errors. The measured x, y point coordinates of this stage were treated as the true undeformed coordinate values. The coordinates of each target were measured four times in four independent rounds and the average discrepancies from the mean were computed. These were used to calculate the overall measurement accuracy values as grand-pooled standard deviations [2]. These were found to be as follows:

$$\sigma_x = \pm 2.1\ \mu m;\ \text{and}$$

$$\sigma_y = \pm 1.9\ \mu m$$

and were viewed as satisfactory for the purpose of the test.

The next stage of the test consists of enlarging the four small-format diapositives to an A-3 format (30 cm x 42 cm) size. A Canon color laser copier bearing code number 2000 with a resolution of around 400 pixels/inch and 256 levels per color (blue, green, red) was used for this purpose.

Each of the four enlarged diapositives was then placed on an Altek Datatab electronic digitizer with a resolution of approximately 25 µm. All targets were then remeasured and stored. Again, great care was exercised in placing the cursor on exactly the center of a cross target when measuring. Before being used for measurement, the Altek Datatab digitizer was made to undergo an accuracy test in order to have an insight into its measuring capability. For this purpose, a high quality standard format (23 cm x 23 cm) glass grid plate was used. A total of 20 grid intersections with known positions were randomly selected and measured with the digitizer three times on three different days (to minimize possible operator bias). An affine transformation algorithm was then computed. An average standard deviation of ± 15 µm was obtained which was viewed as satisfactory for the purpose of the test.

The digitizer measurements made on the enlarged diapositives were compared with their true value equivalents as derived from the Wild AC-1 observations. Again, a least squares affine transofmration was used in this process.

Results and Analysis

Initially, it was thought feasible to compute the amount of image area loss caused by the enlargement process. This was based on theoretical and actual enlargement areas as computed by Warner and Carson [3]. This amounted to an average of 22.8% for the four test images. This figure is in general agreement with those quoted by Needham and Smith [1] (i.e. 16-21%).

The average root-mean-square residuals after the least squares affine transformation fit was about 16 µm at the scale of the original. For the four images, the transformation used also computed the amount of stretch along the x-axis and the mean value of image skewness. Average values were found to be -1.12 mm and 0.91 mm respectively at the enlargement scale. These figures are perfectly comparable with those reported by Warner and Anderson [4] for these two parameters.

Discussion and Conclusion

For small format aerial photography, working with the original scale imagery has the obvious advantages of avoiding errors induced by conventional optical enlarging, namely image area reduction and distortions caused by enlarger lens system. However, in order to make full use of the inherent accuracy of the original image, it is mandatory that measurements be made on an analytical plotter. This is a highly sophisticated and a very expensive instrument which is hard to see outside premises of specialist photogrammetric mapping firms.

By enlarging the original photo, low cost and less accurate measuration equipment, such electronic tablet digitizers could be used with advantage without much loss in the overall accuracy of the imagery. It is clear from the present modest experiment that although causing substantial image area reduction (around 23% on average), laser-scanned enlargements did not introduce appreciable geometric image distortion. A major snag of image area reduction resulting from enlarging small-format photographs relates to the fact that some basic and favorable photogrammetric photo characteristics are to be sacrificed (.e.g. location of frame edges on which to base the vital processes of inner orientation (see [3]). Despite this fact, enlarging small format diapositives with a laser-scanned commercial copier has many advantages to offer, the obvious one being reduced cost. For the present test, an A-3 color enlargement of the diapositives costs only 30% of the expenses that would have been incurred if carried out with conventional optical photogrammetric enlargers.

On the light of the results of this test, the authors therefore appeal to users to photogrammetric mapping techniques to reconsider utilization of electronically enlarged small-format aerial photographs in their respective mapping activities. The method may prove particularly useful for thematic mapping applications e.g. soil and geological surveys, urban planning surveys, agricultural mapping, road route selection etc. where inexpensive mapping tools e.g. tablet digitizers may yield satisfactory results.

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References

[1] Needham, T. and Smith, J.L. "Consequences of Enlarging 35 mm Aerial Photography." *Photogrammetric Engineering and Remote Sensing*, 50, No. 8 (1984), 1143-1144.

[2] Elhassan, I.M. and Ali, A.E. "Radargrammetry with Almaz SAR Imagery." *Geomatics Research Australia*, 62 (1995), 63-92.

[3] Warner, W.S. and Carson, W.W. "Improving Interior Orientation for a Small Standard Camera." *Photogrammetric Record*, 113 (1991), 905-912.

[4] Warner, S.W. and Anderson, O. "Consequences of Enlarging Small-format Imagery with a Color Copier." *Photogrammetric Engineering and Remote Sensing*, 58, No. 3 (1992), 353-355.

الآثار المترية لتكبير الصور الجوية صغيرة الحجم بواسطة ماكينات التصوير الإلكترونية التجارية

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ملخص البحث. كُبِّرت مجموعة من الصور صغيرة الحجم الكترونيا ثم اختبرت لمعرفة الآثار المترية الناجمة عن التكبير. استعمل لهذا الغرض جهاز الرسم الأوتوغرافي التحليلي Wild AC-1 وجهاز ترقيم الكتروني من Altek Data .

أثبتت النتائج أنه على الرغم من أن المساحة الكلية لكل صورة قد نقصت بمقدار حوالي ٢٣٪ أثناء عملية التكبير إلا أن التشوهات المترية التي خلّفتها هذه العملية صغيرة نسبيا. فقد كان متوسط القيم المحسوبة لمقدار التمدد على محور السينات ١٢ , ١م ومقدار درجة انحراف الصور ٩١ , ٠م. وعليه، إذا أخذنا هذه النتائج في الاعتبار مع ملاحظة أن تكاليف تكبير الصور الكترونيا لا تتعدى نسبة ٣٠٪ من قيمة التكبير التقليدي بواسطة الماكينات البصرية تبين لنا أن الصور الجوية صغيرة الحجم المكبّرة الكترونيا يمكن أن تكون مفيدة في الأعمال المساحية التي لا تتطلب استعمال الأجهزة المساحية غالية الثمن والمعقدة تكنولوجيا.