DIGITAL TECHNOLOGY IN PHOTOGRAMMETRY

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ABSTRACT
One of the major advantages of digital photogrammetry is the potential to automate production processes efficiently, thus substantially improving the price \ performance ratio for photogrammetric products. Image processing and computer vision techniques have successfully been employed for facilitating automated procedures in digital aerial images such as interior orientation, relative orientation, point transfer in photogrammetric block triangulation, and the generation of DTM S .

In this paper, the researcher presents her investigations on a digital aerial triangulation of a block consists of two strips of eight aerial photographs. Digital imae data scanned with a resolution of 400 dpi, this gives pixel size of 63.5 μm (corresponding to 0.19m ground resolution. Each one of the eight black-and-white overlapped aerial photograph that have been used in this research has a photo scale equal approximately to 1:3000. The measurements were carried out using Pentium III personal computer with processor (CPU) 733MH,128MB memory and 20GB hard disk. All observations were later adjusted in bundle adjustment program (jadria) that has been written by the researcher herself.

The goal of this research is building a digital aerial triangulation package to be the first trial of digital aerial triangulation in Iraqi Universities .

الخلاصة

ان واحدة من بين الفوائد الرئيسية للمسح التصويري الرقمي هو امكانية تقليل خطوات الانتاج وبكفاءة عالية ، ولهذا يمكن فعليا تحسين القيمة ومعدل الاداء في نتائج المسح التصويري .ان تقنيات المعالجة الصورية (image processing) ورؤية الحاسبة (computer vision) قد طبقت بنجاح لزيادة فعالية خطوات العمل أوتوماتيكيا في الصور الجوية الرقمية مثل التوجيه الداخلي (interior orientation) والتوجيه النسبي (relative orientation) ونقل النقاط (point transfer) في عمليات التثليث الجوي لمنطقة معينة وكذلك في انتاج نمذجة الارتفاعات رقميا (DTM) .

في هذا البحث قدمت الباحثة دراستها عن موضوع التثليث الجوي الرقمي الذي طبق على مجموعة من الصور المتوفرة لمنطقة الدراسة والمكونة من ثمانية صور. هذه الصور تم تحويلها الى الصورة الرقمية باستخدام جهاز المشاط الالكتروني وبوضوح مقداره(400dpi) والذي يعادل قوة وضوح على سطح الارض مقداره (0.19m). كل صورة من الصور المتداخلة والمستعملة في هذا البحث لها مقياس صوري يساوي حوالي (1:3000). القياسات التي اجريت على هذه الصور تمت باستخدام حاسبة شخصية نوع (pentiumIII)

ذات سرعة تساوي (733MH) وذاكرة حجمها (128MB) وسعة خزن تساوي (20GB). هذه القراسات تم تصحيحها لاحقا باستخدام اسلوب التصحيح بطريقة الاشعة وبرنامج (jaderia) الذي تم كتابته من قبل الباحثة. ان الهدف من هذا البحث هو بناء مجموعة من البرامجيات المتكاملة لعملية التثليث الجوي الرقمي ليكون أول تجربة في التثليث الجوي الرقمي في الجامعات العراقية.

KEY WORDS
Surveying, Photogrammetry , Digital Aerial triangulation

INTRODUCTION

Digital aerial triangulation has been an increasingly interesting topic of research and developmen in digital photogrammetry for a number of years. The two tasks of measuring the image coordinate of tie points and of computing the orientation parameters, which were well separated in analytica photogrammetry, are more and more being merged into a single process. At the same time a shift c focus concerning the results of aerial triangulation can be observed. While in earlier times poin densification was the primary goal, currently the orientation parameters themselves are of growin importance.

Over the last few years various digital aerial triangulation software systems with different degree o automation have been developed and have become commercially available, either as stand-alon packages or as part of a Digital Photogrammetric Workstation. These systems have been introduce into practice, and users have started to report on obtained results.

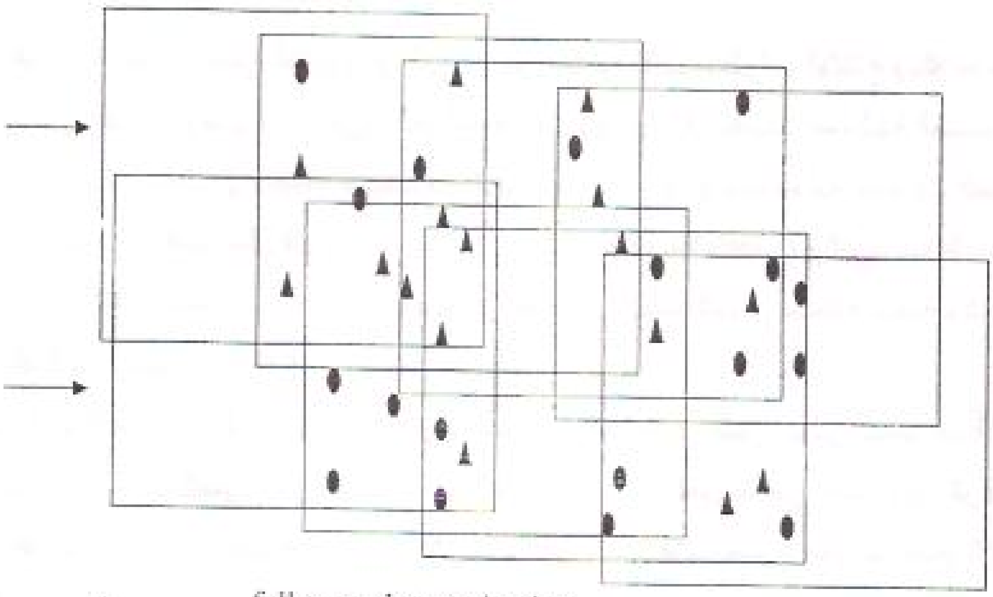
THE STUDY AREA

Here in this work, two strips of eight aerial photographs having an approximate scale of 1:3000 for part of Baghdad City showing Baghdad University. The block contains 16 full ground control points; with 4 check points **Fig. (1)**.

Black and white overlapped aerial photographs are used to generate the ground positions of the tie-pass points, and the specifications of these photographs are shown in **Table (1)**.

110

111



▲ full ground control points
● tie-pass points

Fig. (1) The Block Under Study

Table (1) Specifications of the used photographs

The study area	Baghdad
Camera type	MRB /15 (W.A.)
No. of strips	2
No. of photos per strip	4
Photo scale	1: 3000
Flying height	456.48 m.
Focal length	152.16 mm.
Forward overlap	60%
Side lap	60%
No. of fiducial marks per photo	4
Format	23 × 23 cm.
Date	July 1985

DIGITAL AERIAL TRIANGULATION STEPS

In an automated production, the digital aerial triangulation in this research is divided into several processing steps, which include, scanning the photographs, measuring the pixel position of each point appears in each photo, using affine transformation to transform the machine into photo coordinates, and finally using bundle block adjustment to compute the ground positions of the tie-pass points [Thomas Kersten, 1999].

Scanning of The Aerial Photographs:

Eight black-and-white overlapped aerial photographs are used. They are scanned at a resolution of 400 dpi, this gives pixel size of 63.5 μm (corresponding to 0.19 m ground resolution) on a LG Scanner.

A Pentium computer with processor (CPU) 733 MH is used in this work. It has a 128 MB memory and 20 GB hard disk. This computer is supplied with a 3.5 high-density floppy disk and a mouse. A super VGA color display monitor with 640 × 480 pixels is used to display image data on the screen. These kinds of computers are necessary to deal with this kind of work (especially to increase the speed of matching techniques).

Measurements of The Scanner Coordinates Using Matching Techniques

The measurements of the scanner coordinates on digital images is done using digital stereo image matching package, and this is done after the photos being digital and stored on the hard disk of the computer.

The major steps in this scheme that used in this research are listed below:

1- Edge detection for both images to generate a binary valued image from a detailed one containing the boundaries of the scenes or objects within the original image. The original (left) image f (x, y) undergoes a gray scale edge enhancement by linear or non-linear processing to produce the right image field g (x,y) with accentuated spatial brightness changes. Next a threshold operation is performed to determine the pixel location of significant edges.

2- Find the most interest points to be matched from the output of step 1. For the highest level (n), interest points are extracted. The edge map, which is a binary image, can be used to extract the interest points. The interest points' extraction depends on the information content within each window, which is measured by calculating the number of edge pixels within the window.

3- Cross-correlation between the left & right photos using cross-correlation factor > 0.98 depending on the pixel locations resulted from step 2. The cross-correlation measure between a template (T) and the search region at location (u,v) can be implemented as follows:

$$R(u,v)=\sum_{x}\sum_{y} S(x,y)T(x+u,y+v) \quad (1)$$

The correlation function given in eq. (1), although simple in nature, has the drawback that it is sensitive to such changes in amplitude of $S(x,y)$ and $T(x,y)$. Even though cross-correlation is an accurate method to find the similarity of two windows; it tends to fail in case of scaling and rotation, if the rotation angle is relatively large [Mohamed A. Naji, 1994].

Transformation Of Digitizing System To Image System

To transform the points locations from the digitizing system (column & row) to the aerial image system (x & y), the two-dimensional Affine coordinate transformation has been used. The term two-dimensional means that the coordinate systems lie on plane surface [Fadhil H. Abdul-Rudah,1999].

In the case of this work the (XY) comparator coordinates system was represented by the digitizing system (column & row) (computer screen system). While the image system was represented by the (xy) digital aerial image system. The control points that used to solve this transformation were the classical four fiducial marks.

The system of equations that obtained from applying the least squares method to equations (2) & (3)

$$x=a_1+a_2X+a_3Y \quad (2)$$

$$y=b_1+b_2X+b_3Y \quad (3)$$

which named as the observation equations, can be expressed in matrix form as follows:

$$A\cdot X=L+V \quad (4)$$

where:

$$A_{8*6}=\begin{bmatrix}1 & X_1 & Y_1 & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & X_1 & Y_1\\ 1 & X_2 & Y_2 & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & X_2 & Y_2\\ 1 & X_3 & Y_3 & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & X_3 & Y_3\\ 1 & X_4 & Y_4 & 0 & 0 & 0\\ 0 & 0 & 0 & 1 & X_4 & Y_4\end{bmatrix} \qquad X_{6*1}=\begin{bmatrix}a_1\\ a_2\\ a_3\\ b_1\\ b_2\\ b_3\end{bmatrix} \qquad L_{8*1}=\begin{bmatrix}x_1\\ y_1\\ x_2\\ y_2\\ x_3\\ y_3\\ x_4\\ y_4\end{bmatrix} \qquad V_{8*1}=\begin{bmatrix}v_{x_1}\\ v_{y_1}\\ v_{x_2}\\ v_{y_2}\\ v_{x_3}\\ v_{y_3}\\ v_{x_4}\\ v_{y_4}\end{bmatrix}$$

The Approximate Values

The bundle adjustment needs as starting values approximate values of the orientation parameters of all photographs and of the unknown coordinates of all terrain (tie-pass) points. If good approximate values of the orientation parameters are available, they should be supplied to the program. Starting from such values, only one iteration of the adjustment will be needed [G.H.Schut, 1980].

A space resection of the scanned photograph using available ground control and the corresponding photo coordinates is used to compute the approximate values of the elements of the exterior orientation. These elements are the spatial coordinates of the projection center (X_L, Y_L, Z_L) and the three rotation angles (ω, ϕ, χ) [Shaker Farhan Ahmed,1999]. The resulting photo coordinates of the control points together with the corresponding ground coordinates are used to solve space resection problem.

The linearized forms of the space resection collinearity equations are [Wolf, Paul R., 1982]

$$v_x = b_{11}d\omega + b_{12}d\phi + b_{13}d\chi - b_{14}dX_L - b_{15}dY_L - b_{16}dZ_{L+J} \quad ...(5)$$

$$v_y = b_{21}d\omega + b_{22}d\phi + b_{23}d\chi - b_{24}dX_L - b_{25}dY_L - b_{26}dZ_L + K \quad ...(6)$$

where:

$v_x \,\&\, v_y$	residual errors in measured $x\&y$ image coordinates
$d\omega, d\phi, \& d\chi$	corrections to initial approximations for the orientation angles of the photo
$dX_L, dY_L, \& dZ_L$	corrections to initial approximations for the exposure station coordinates

The collinearity equations can be used to determine the approximate values of the X, Y, and Z ground coordinates of the tie-pass points whose images appear in the overlap area of a stereo pair of vertical photos. This procedure is called space intersection. Space intersection requires that the six elements of exterior orientation for the two overlapping vertical photos be known. The linearized forms of the space intersection equations for point E are [Wolf, Paul R., 1982]:

$$v_{x_e} = b_{14}dX_E + b_{15}dY_E + b_{16}dZ_E + J \qquad (7)$$

$$v_{y_e} = b_{24}dX_E + b_{25}dY_E + b_{26}dZ_E + K \qquad (8)$$

where:

$v_{x_e} \,\&\, v_{y_e}$	residual errors in measured $x \,\&\, y$ image coordinates of point e

$dX_E, dY_E, \& dZ_E$

corrections to initial values of the object space coordinates of the point E

Applying The Least Squares Adjustment (Bundle Method) Of TheCase Study

A simultaneous least squares adjustment of all the measurements in a photogrammetric mapping problem can be formulated by the use of condition and observation equations. In the case of digital aerotriangulation, the basic measurements include:(1) the photo coordinates of the relevant image points on the photographs; (2) the ground coordinates of at least three control points; and (3) auxiliary data on the exterior orientation of the photographs. The purpose of the least squares adjustment is then to determine the most probable solution for the ground coordinates of all the unknown points and the exterior orientation parameters of all the photographs [Salama C.C., 1980]. The bundle method projective relationship between the ground space coordinates of a point and the image plane coordinates can be derived from a re-arrangement of the general math model:

$$x = -f\left[\frac{m_{11}(X - X_i) + m_{12}(Y - Y_i) + m_{13}(Z - Z_i)}{m_{31}(X - X_i) + m_{32}(Y - Y_i) + m_{33}(Z - Z_i)}\right] \quad (9)$$

$$y = -f\left[\frac{m_{21}(X - X_i) + m_{22}(Y - Y_i) + m_{23}(Z - Z_i)}{m_{31}(X - X_i) + m_{32}(Y - Y_i) + m_{33}(Z - Z_i)}\right] \quad (10)$$

For each image point measured on the eight photographs of this block that consists of two strips (110,111), one pair of equations like the above can be written. A typical bundle triangulation solution solves for the exposure parameters and unknown ground coordinates.

The observation equations for photo coordinates will be [Salama C.C., 1980]:

$$V_{ij} + \dot{B}_{ij}\dot{\Delta}_i + \ddot{B}_{ij}\ddot{\Delta}_j + E_{ij} = 0 \quad (11)$$

for j= points in the object space=1,n, where n equal to no. of points that appear in each photo which differs from photo to photo. i= no. of photos, in this case i=1,8

Where:

$$V_{ij} = \begin{bmatrix} V_{1j} \\ V_{2j} \\ \cdot \\ \cdot \\ V_{8j} \end{bmatrix}, \quad \dot{B}_j = \begin{bmatrix} \dot{B}_{1j} & & & 0 \\ & \dot{B}_{2j} & & \\ & & \cdot & \\ & & \cdot & \\ 0 & & & \dot{B}_{8j} \end{bmatrix}, \quad \ddot{B}_{ij} = \begin{bmatrix} \ddot{B}_{1j} \\ \ddot{B}_{2j} \\ \cdot \\ \cdot \\ \ddot{B}_{8j} \end{bmatrix}$$

$$\overset{e}{\Delta}_i = \begin{bmatrix} \overset{e}{\Delta}_1 \\ \overset{e}{\Delta}_2 \\ . \\ . \\ \overset{e}{\Delta}_8 \end{bmatrix} \qquad \overset{s}{\Delta}_j = \begin{bmatrix} \overset{s}{\Delta}_1 \\ \overset{s}{\Delta}_2 \\ . \\ . \\ \overset{s}{\Delta}_n \end{bmatrix} \qquad E_{ij} = \begin{bmatrix} E_{1j} \\ E_{2j} \\ . \\ . \\ E_{8j} \end{bmatrix}$$

The observation equations for exterior orientation parameters will be: -

$$\overset{e}{V}_i - \overset{e}{\Delta}_i + \overset{e}{E}_i = 0 \qquad (12)$$

Where

$$\overset{e}{V}_i = \begin{bmatrix} \overset{e}{V}_1 \\ \overset{e}{V}_2 \\ . \\ . \\ \overset{e}{V}_8 \end{bmatrix} \qquad \overset{e}{E}_i = \begin{bmatrix} \overset{e}{E}_1 \\ \overset{e}{E}_2 \\ . \\ . \\ \overset{e}{E}_8 \end{bmatrix}$$

The observation equations for survey coordinates will be:

$$\overset{s}{V}_j - \overset{s}{\Delta}_j + \overset{s}{E}_j = 0 \qquad (13)$$

where

$$\overset{s}{V}_j = \begin{bmatrix} \overset{s}{V}_1 \\ \overset{s}{V}_2 \\ \cdot \\ \cdot \\ \overset{s}{V}_n \end{bmatrix}, \quad \overset{s}{\Delta}_j = \begin{bmatrix} \overset{s}{\Delta}_1 \\ \overset{s}{\Delta}_2 \\ \cdot \\ \cdot \\ \overset{s}{\Delta}_n \end{bmatrix} \quad \overset{s}{E}_j = \begin{bmatrix} \overset{s}{E}_1 \\ \overset{s}{E}_2 \\ \cdot \\ \cdot \\ \overset{s}{E}_n \end{bmatrix}$$

The collection of all observation equations mentioned above will be :

$$\overline{V} + \overline{B}\,\overline{\Delta} + \overline{E} = 0 \qquad (14)$$

where:

$$\overline{V} = \begin{bmatrix} V_{ij} \\ \overset{e}{V}_i \\ \overset{s}{V}_j \end{bmatrix} \quad B = \begin{bmatrix} \overset{e}{B}_{ij} & \overset{s}{B}_{ij} \\ -I & 0 \\ 0 & -I \end{bmatrix} \quad \overline{\Delta} = \begin{bmatrix} \overset{e}{\Delta}_i \\ \overset{s}{\Delta}_j \end{bmatrix} \quad \overline{E} = \begin{bmatrix} E_{ij} \\ \overset{e}{E}_i \\ \overset{s}{E}_j \end{bmatrix}$$

The normal equations for the case study are:

$$\overline{B}^T \overline{W}\,\overline{B}\,\overline{\Delta} + \overline{B}^T \overline{W}\,\overline{E} = 0 \qquad (15)$$

or

$$\overline{N}\Delta + \overline{U} = 0 \qquad (16)$$

The weight matrix here ($\overline{W}$) is taken as:

$$\overline{W} = \begin{bmatrix} W_1 & & & & 0 \\ & \ddots & & & \\ & & W_s & & \\ & & & \overset{e}{W} & \\ 0 & & & & \overset{s}{W} \end{bmatrix}$$

After substituting the values of $\overline{E}, \overline{W}$, and $\overline{B}$ the result will be:

$$\begin{bmatrix} \overset{e}{B}^{T} W \overset{e}{B} + \overset{e}{W} & \overset{e}{B}^{T} W \overset{s}{B} \\ \overset{s}{B}^{T} W \overset{e}{B} & \overset{s}{B}^{T} W \overset{s}{B} + \overset{s}{W} \end{bmatrix} = \overline{N} = \begin{bmatrix} \overset{e}{N} + \overset{e}{W} & \overset{es}{N} \\ \overset{es}{N}^{T} & \overset{s}{N} + \overset{s}{W} \end{bmatrix}$$

where:

$$\overset{e}{N} = \overset{e}{B}^{T} W \overset{e}{B}$$

$$\overset{e}{B} = \begin{bmatrix} \overset{e}{B}_{1} & & \\ & \ddots & \\ & & \overset{e}{B}_{8} \end{bmatrix} \qquad W = \begin{bmatrix} W_{1} & & 0 \\ & \ddots & \\ 0 & & W_{8} \end{bmatrix}$$

CNCLUSIONS

1- All softwaresthat are built in this work are efficient and successful in performing digital aerial triangulation process; these softwares are free of errors either on mathematical or programming sides.
2- Digital data preparation by using scanning technique is a basic step in digital arial triangulation,and all the next steps depending on it,so must be performed to have a high resolution and a suitable pixel size using a large scanner format.

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