DESIGNING AND DEVELOPING A FULLY AUTOMATIC INTERIOR ORIENTATION METHOD IN A DIGITAL PHOTOGRAMMETRIC WORKSTATION

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ABSTRACT:

This paper is concerned with a comparative study and implementation of different image correlation techniques for Automatic Inner Orientation in aerial images.
The implemented image correlation techniques are:
Cross Correlation Function (CCF), Binary Cross Correlation Function (BCCF) and Least Square Matching (LSM). The first two approaches are used to determine the approximate position of the fiducial mark centres, which is then followed by a quadratic surface fitting for precise fiducial centre determination. Wiener and constrained least square filter were used as pre-processing techniques to improve the accuracy of algorithms.
All three algorithms are applied to the digital images with different resolution (namely: 15, 30 and 60 micrometers pixel size).
The test results show that the optimum solution can be achieved by a combination of CCF for approximate positioning followed by LSM method, i.e. LSM approach shows better performance as far as pointing precision for fiducial mark(cross type)centres have been 4.2 and 4.7 micrometers respectively when the optimum solution (i.e. CCF plus LSM)is used. Other aspects of fully automatic Digital Inner Orientation with respect to image frame direction, and determination of whether or not a mirror image is scanned are also investigated. The designed algorithms have the capability to achieve the accuracy mentioned above in any frame from different aerial cameras.

1. INTRODUCTION

Although Several decades have passed since scientists in the photogrammetric community started research work related to automation of different processes in photogrammetry and remote sensing, with the dramatically fast progress of computer technology, great developments have occurred in recent years.
With precise scanners and high memory fast performing computer systems, the possibility of automation in Digital Photogrammetric Workstations (DPW) has increased. New techniques such as machine vision and digital image processing and the trend of commercial photogrammetric companies in using DPW made the research grow quicker.
Inner orientation is a prerequisite for any project including 3D computation as it is a complicated and time-consuming process which making it automatic helps us to open a broad range of applications. Among orientations (inner, relative and absolute) inner orientation has a special importance as any inaccuracy will affect next stages in photogrammetric processes.
In 1995, Phodis Company developed a method of fully automatic inner orientation with overall accuracy of 0.2 pixel and pointing accuracy of any individual fiducial mark of 0.1 pixel.

2. INNER ORIENTATION AND AUTOMATION FEATURES

In inner orientation process, we establish a geometric relationship between photo coordinate system and instrument coordinate system. In metric imaging system, photo coordinate system is defined by fiducial marks but in field of digital photogrammetry instrument coordinate system is replaced by pixel coordinate system. Image coordinate system is defined by the matrix including grey values but photo coordinate system is defined by fiducial marks positions. If the relationship between scanner and camera coordinate system remain constant, inner orientation will be eliminated from digital photogrammetric stages. We have not had the chance of using such digital cameras to prepare high resolution images yet.
We would be able to design an algorithm to achieve the goal of performing interior orientation automatically if it is possible to have a good knowledge of location, shape, illumination distribution and sizes of fiducial marks in digital scanned aerial photos. With respect to fully automation procedure concept, the algorithm should be able to include features listed below:
1- using images from various cameras
2-using colorful and black & white images
3-using fiducial marks with different of shapes
4-using images with different pixel size
5-using positive or negative images
6-using mirror images
7-using rotated images
8-using images scanned in different scanners

3. DESIGNING AND IMPLEMENTING

With respect to the kind of input data, several methods can be taken into account, however, two distinct algorithms performing two major successive stages of localization and precise measurement differently and other minor six stages commonly.
The six common stages are:
1-extracting image patches
2-resampling the template
3- Image pyramid derivation
4- Detection of the orientation of the image
5-positive-negative recognition

6-Estimation of the transformation parameters
The whole procedure of automatic interior orientation (AIO) is shown in Fig.1.
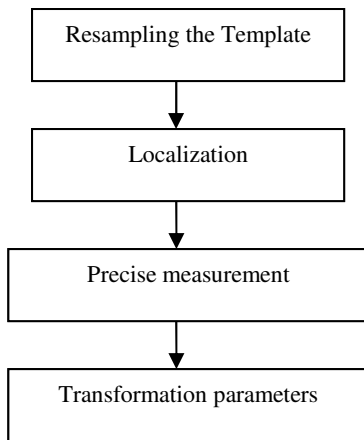

Figure 1: The whole procedure of AIO

3.1 Extracting image patches

To do the job, one doesn't need to use the whole image so we just extract the patch including fiducial mark and its surrounding (Fig.2). This helps us to reduce the amount of information and to rise the speed of computation. The size of patch is dynamically changing in correlation to the image size.

Figure 2: Extracted image patch

3.2 Resampling the template

How to resample the template affects the success and accuracy of LSM (Least Square Matching) and output data as more we improve the quality of template more accurate output data and LSM algorithm will be. Here, since we knew the kind of camera so we resampled the template from the extracted patches and improved its quality by several pre-processing steps to be used by LSM algorithm (Fig.3).

Figure 3: Desired mask

3.3 Image pyramid derivation

On different pyramid levels we use different representations for the fiducials. On highest levels we use the whole fiducial mark including its surrounding(Fig.4 left).On the lower levels the fiducial figure (Fig.4 middle), and only on the lowest level where final measurement is done, the fiducial mark itself is used (Fig. 4 right).
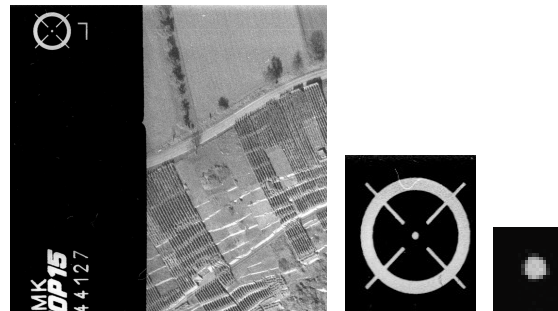

Figure 4. Left: Pattern of fiducial mark and its surrounding. Middle: Pattern of the fiducial mark figure. Right: Pattern of the fiducial mark.

3.4 Detection of the orientation of the image

There are eight different possible orientations how to scan an image, i.e. wrong reading or right reading with four different multiple $90°$ rotations respectively. In general, fiducials are normally located on the corners and/or edges of a film as shown in Fig. 5. To detect the correct orientation, we analyze the order of fiducial mark's numbers.
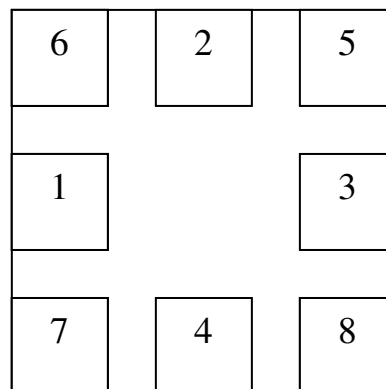

Figure 5. Fiducial distribution on an aerial photo and the numbering sequence by USGS of the USA.

3.5 Positive-negative recognition

During the localization stage, algorithm recognizes if the extracted patch is positive or negative. In case of negative, the patch converts to positive. The values of grey value correlation matrix help us to determine if mask is positive and image is negative so the values of grey value correlation matrix become negative. In case that mask and patch are positive, the matrix of grey value correlation has positive values.

3.6 Estimation of the transformation parameters

Now the accurate positions of fiducial marks were known and the position of which in photo coordinate system are available through camera calibration file. To establish a geometric relationship between pixel and photo coordinate system, projective transformation is used to achieve this goal.

At least exact position of four out of eight fiducial marks should be known (Eq.1)

$$x' = \frac{a_1 x + b_1 y + c_1}{a_3 x + b_3 y + 1} \tag{1}$$

$$y' = \frac{a_2 x + b_2 y + c_2}{a_3 x + b_3 y + 1}$$

where:

$[a, b, c]$ = Transformation parameters

$[x', y']$ = Photo coordinates of fiducial marks

$[x, y]$ = Pixel coordinates of fiducial marks

3.7 Localization

From various methods used to localize the fiducial mark, we chose two methods which help us to obtain a better accuracy as follow:

3.7.1 Cross Correlation Function (CCF)

In this method, a small patch with a search area of 512 by 512 pixels is read from the original image called (f).Template of fiducial mark (w) is conducted to search over the top level of pyramid of extracted patches until the best match between the template and a certain patch is found. Template(w) moves over the search window one by one pixel forward systematically and in every step normalized correlation coefficient is calculated which indicated the best match between (w) and (f) when value of (r) is maximum as shown in Eq.2.
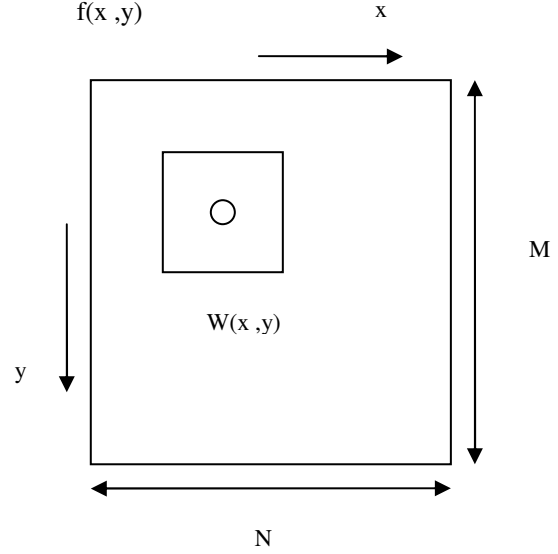

Figure 6. Arrangement for the obtaining of f(x, y) and w(x, y) at a given point

$$r(m,n) = \frac{\sum_x \sum_y [f(x,y) - \bar{f}] \, [w(x-m, y-n) - \bar{w}]}{\left[\sum_x \sum_y [f(x,y) - \bar{f}]^2 \sum_x \sum_y [w(x-m, y-n) - \bar{w}]^2 \right]^{1/2}} \tag{2}$$

Where:

$\bar{w}$ = the average value of the pixels in w(x, y).

$\bar{f}$ = the average value of f(x, y) in the region coincident with the current location of w

$r(m, n)$ = normalized correlation coefficient at a given point of (m, n)

The summations are taken over the coordinates common to both f and w. The correlation coefficients are scaled in the range of -1 to 1. In case of the best matching, the number would be 1.

3.7.2 Binary Cross Correlation Function (BCCF)

This method is similar to the previous one with the difference of using binary patch and template windows. What is important is how to estimate the amount of a suitable threshold for this purpose.

3.8 Precise measurement

In this Paper we used two more accurate methods as follow:

3.8.1 Interpolation and surface fitting (ISF)

In this method, we fit a bilinear surface (Eq.3) on the approximate pixel position obtained from previous stage and its surrounding.

The precise position with sub-pixel accuracy will be gain by derivation of the bilinear surface as shown in Fig. 7.
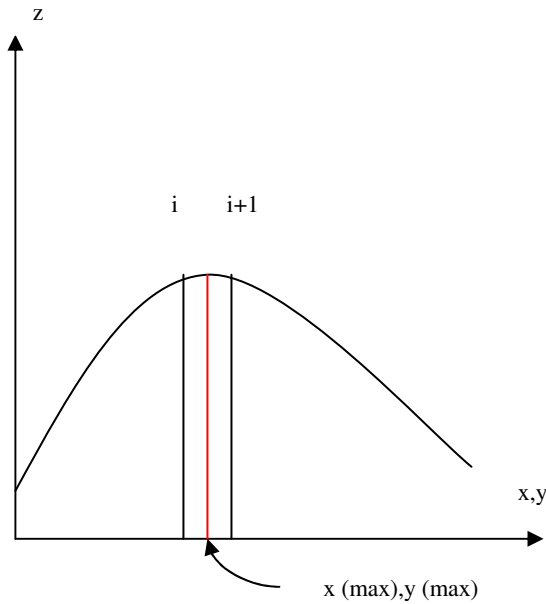
Figure 7. Finding the maximum point

$$z = ax^2 + by^2 + cx + dy + exy + f \qquad (3)$$

For the area-based template matching, the locating accuracy ranges from a half to one pixel, which is, of course, not accurate enough for most photographic products.

3.8.2 Least Square Matching(LSM)

Precise measurements of all fiducial marks were performed by matching the extracted patches. The algorithm used is known as least square image matching, which allows point measurements with sub-pixel accuracy and is described in Gruen and baltsavias(1988). In these investigations, the algorithm was used in its unconstrained mode using an real template which was read from the original file is used. The accuracy of the matching algorithm is dependent on the used templates. Thus, the generation of templates for each camera type is an essential factor. The result from the template matching is definitely good enough for a successful LSM processing (half or one pixel). Here is the equation we used for the system (Eq.4).

$$g(x, y) = h_1 f(x + p_x, y + p_y) + h_0 \qquad (4)$$

$f(x, y)$ = The template

$g(x, y)$ = The picture

(p_x, p_y) = Transformation parameters

h_1, h_2 = Two radiometric parameters of scale and shift respectively

The initial values = $(p_x, p_y, h_1, h_0)^0 = (0,0,1,0)$

4. Tests and Results

The Results of all three algorithms implemented can be seen at three tables below. Input data for any algorithm is first, images of RMK camera of Ziess Company of Germany second, camera calibration file including position of fiducial marks in a standard conditions of labratory. Output data includes final report including positions of fiducial marks in pixel system, residual errors of fiducial coordinates, RMSE(Root Mean Square Error) and the pose of the photo on scanner seen on the designed menu(Fig. 8). Images were scanned on two resolutions of 30 and 15 micrometer by Intergraph PhotoScan TD. In all tables ∂ is the overall accuracy of the automatic interior orientation process in micrometer.

Resolution	∂_{mean}	∂_{max}	∂_{min}
15	3.5	5.7	4.7
30	2.2	6.1	4.2

Table 1. : The results of using CCF method for localization and LSM for precise measurement

Resolution	∂_{mean}	∂_{max}	∂_{min}
15	4.1	6.2	5.4
30	3.5	7.2	5.4

Table 2. : The results of using BCCF method for localization and LSM for precise measurement

Resolution	∂_{mean}	∂_{max}	∂_{min}
15	3.7	6.1	5
30	2.6	6.4	4.5

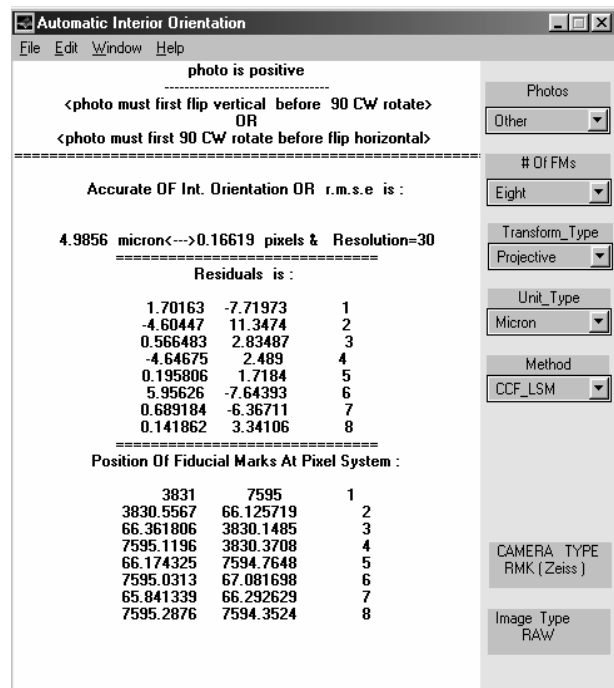Table 3. : The results of using CCF method for localization and ISF for precise measurement

Figure 8. A sample of designed menu

5. Conclusion

According to the results obtained from various tests done on different photos in different pixel size, our suggested method is GVC for rough localization and LSM for precise positioning.

One major problem can occur if older cameras have been used for the acquisition of the analogue film images: the fiducial center is not as bright as expected. In newer cameras, the fiducials are often illuminated by light emitting diods (LEDs).

Dust and scratches in the images around the fiducials and scanning with out proper parameter settings can further decrease the quality of the fiducials in the digital image and that may lead the algorithm to fail. We use Wiener and constrained least square filter as pre-processing techniques to improve the accuracy and reliability of the algorithms but we observed no affect on accuracy, however, they improve the quality of the patches and make them sharper.

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