AUTOMATIC INTERIOR ORIENTATION OF KFA-1000 SPACE PHOTO

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Commission II/IV

KEY WORDS: Orientation, Accuracy, digital, Transformation, Space, Algorithms

ABSTRACT:

This paper concerned with a comparative study and implementation of Interior orientation manually and automatically for KFA-1000. In manually method, firstly, we reproduced the image to its reduced size photographically from the original image to be measurable in a mono comparator from 30*30 cm to 23*23 cm which proceeds by measuring of photo coordinates of four pieces of KFA-1000 photo. After computation, it was realized that geometric distortion due to photography is high so the chosen method is to make a photographic reproduction of the image in suitable pieces, measuring with traditional instruments and pining the pieces together before calculation. In the second method, we scanned the space photo and used digital image processing techniques in which CCF (Cross correlation Function) and BinaryCCF were used to approximate positioning followed by quadratic surface fitting for the purpose of precise fiducial centre determination. In both methods, we applied three types of transformation called Conformal, Affine and 2D projective to the algorithms.

The final results showed that we could achieve sub-pixel accuracy of nearly 10 micrometer for 25 micrometer pixel size image by using 2D projective transformation which is approximately equal to the accuracy achieved in manual method. With respect to differences between aerial and KFA-1000 photos, we considered those differences and applied them to the algorithms used in both fields (aerial and space) particularly different background at location of each fiducial mark in KFA-1000 which made us to resample a suitable template while in aerial photos backgrounds in any photo are similar with good contrast which guarantee the robustness of the algorithms. We also examined the effect of pre-processing techniques on the robustness of algorithm and took into account the results.

1. INTRODUCTION

Image 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. Due to its decisive importance, image orientation has always been a focus of attention in photogrammetry. Digital photogrammetry holds the promise of completely automating the process of image orientation using image processing and image analysis techniques. It is interesting to note in this context that in the computer vision terminology "image calibration" sometimes already includes image orientation. Image orientation refers to the determination of parameters describing specific photogrammetric models for mapping geometric primitives such as points, lines, and areas from one coordinate system to another one. Thus, image orientation belongs to the class of coordinate transformation problems. Among orientations (inner, relative and absolute) inner orientation has a special importance as any inaccuracy will affect next stages in photogrammetric processes.

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 fidcual 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 KFA-1000 photos. With respect to fully automation procedure concept, the algorithm should be able to include features listed below:

1-using images with different pixel size
2-using positive or negative images
3-using mirror images
4-using rotated images
5-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.
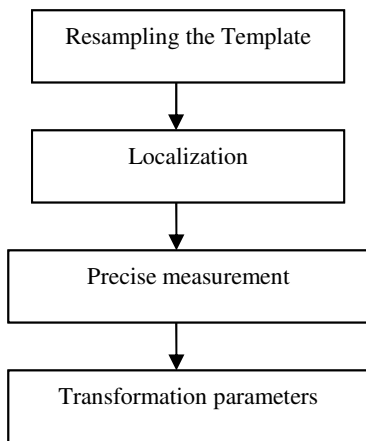
Figure 1: The whole procedure of AIO

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 increase the speed of computation. The size of patch is dynamically changing in correlation to the image size.
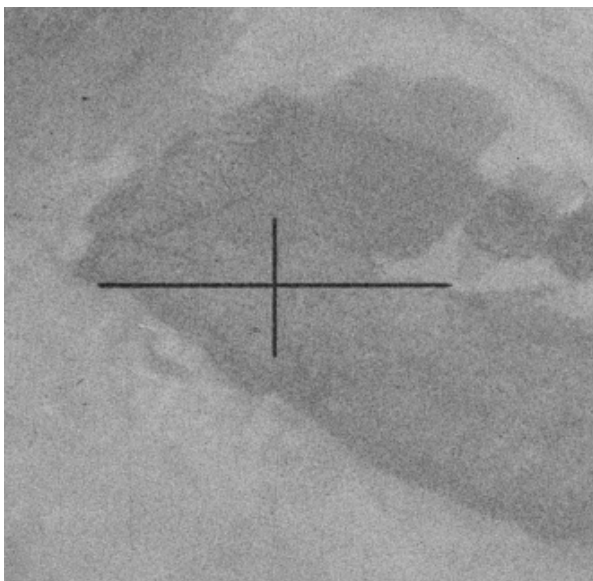

Figure 2: Extracted image patch

3.2 Resampling the template

How to resample the template affects the success and accuracy of TM (Template Matching) and output data as more we improve the quality of template more accurate output data and Template Matching 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 TM algorithm (Fig.3).
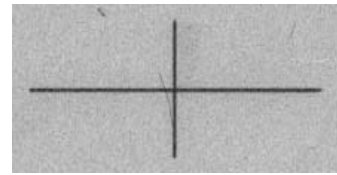

Figure 3: Desired mask

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 Right), and only on the lowest level where final measurement is done, the same which was used for previous step is used (Fig. 4 Right).
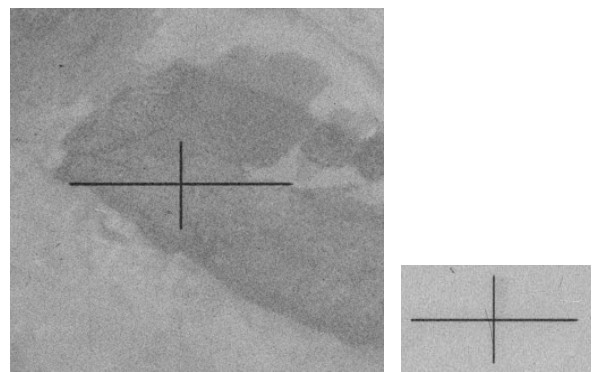

Figure 4. Left: Pattern of fiducial mark and its surrounding. Right: Pattern of the fiducial mark figure.

3.4 Detection of the orientation of the image

In KFA-1000 photos, four of the fiducials are normally located in the center of each side of the photos and the fifth one is located in photo center as shown in Fig. 5. We employed two techniques of TM (Template Matching) with combination with calculating moments parameters which are independent of image rotation to determine the tolerance rotation of (-3,3).
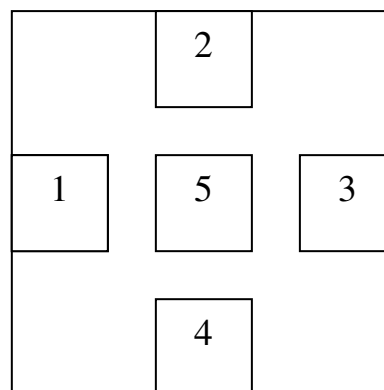

Figure 5. Fiducial distribution on a KFA-1000 photo

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 the 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 in pixel system are known and their position in photo coordinate system are available through camera calibration file also. 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.
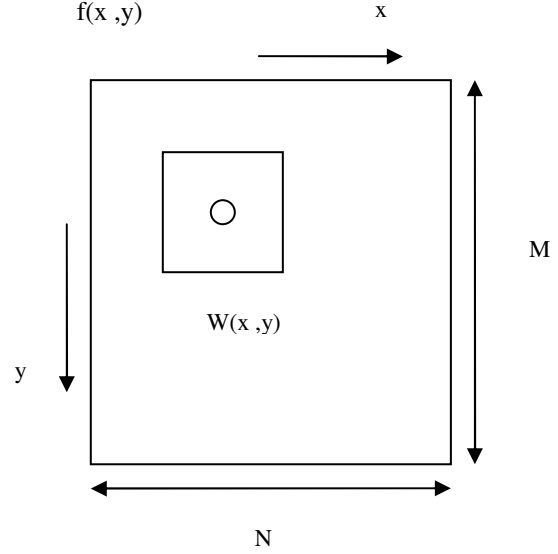

Figure 6. Arrangement for the obtaining of f(x, y) and w(x, y) at a given point

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

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.

3.8 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.
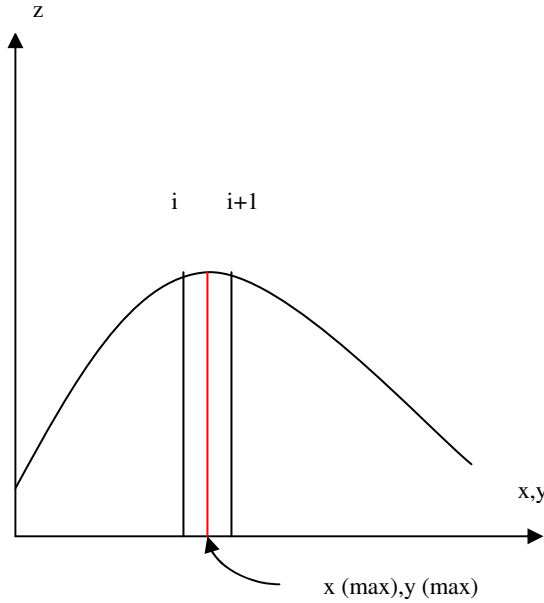
Figure 7. Finding the maximum point

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

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.

4. Analogue Inner orientation

There was no available photogrammetric instrument in Iran of sufficient accuracy that could be used because of the large format of the photos (30*30cm). Ways of overcoming the problems can be as follows: 1) Making a photographic reproduction of the image in suitable pieces, measuring with traditional instruments and pinning the pieces together before calculation. 2) Shipping the image to a foreign institution which has image carriers of sufficient size. 3) Reproducing the image photographically from the original 30*30cm^2 size to 23*23 cm^2 to be measurable in a mono comparator. 4)Using overlapping copies (23*30)^{cm} in Planicomp P1, analytical plotter. 5) Scanning the space photos and use the digital photogrammetric and image processing systems. Initially the third method was used. For determination of geometric distortion of camera a grid was used and then the grid and its photo were measured. After computation, it was realized that geometric distortion due to photography is high (150 micron) and the root mean square errors of residuals was 530 micron because of large lens distortion of camera, therefore, the first method was employed.

4.1. Pinning the pieces together

After making a photographic reproduction of the image in suitable pieces and measuring with traditional instruments, the pieces are then joined together before calculation. The pieces of one KFA-1000 photo pinned with conformal using at least four common points. The result of pinning the 17957 KFA-1000 photo being displayed in Table 1.

Points	Vx(micron)	Vy(micron)
1	1	-1
2	1	7
3	1	-3
4	-2	-2
5	-1	0

Table 1. Results of pinning

4.2. Systematic errors of KFA-1000 photos

The additional parameters of radial distortion of the power of five were computed. Film shrinkage is corrected with affine and projective transformation. Affine inner orientation was made with 4 or 5 fiducial marks, the accuracy of the 17957 KFA-1000 photo displayed in Table 2. To take into consideration the linear distortion in any direction, a two dimensional projective transformation with 5 fiducial marks was employed and the accuracy was better than 10 microns. The refraction correction is below 2 micron.

Fiducials	Vx (micron)	Vy(micron)
1	2	2
2	2	3
3	3	-3
4	3	-3
5	-12	1

Table 2. Results from the inner orientation

5. Tests and Results

The Results of the algorithms implemented can be seen at table 3. Input data inculdes KFA-1000 scanned photo, 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). Images were scanned on the resolutions of micrometer by Intergraph PhotoScan TD. In all tables ∂_{mean} is the overall accuracy of the automatic interior orientation process in micrometer. In table 4. we compare the results achieved by using Analogue and Digital method.

Transformation	∂_{mean} excluding fiducial mark number 5	∂_{mean} including fiducial mark number 5
Conformal	25.80	23.65
Affine	23.84	20.92
Projective	-	10.38

Table 3. The results of using CCF method for localization and Surface Fitting for precise measurement

Transformation	Analogue ∂_{mean}	Digital ∂_{mean}
Affine	10	10.38

Table 4. The overall accuracy obtained by Analogue and Digital methods

6. Conclusion

According to the results obtained from various tests done on the scanned photo in pixel size of 25, our suggested method is CCF for rough localization and ISF 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 diodes (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. For precise measurement, we employed Least Square Matching(LSM) but not a acceptable result could obtain. That was because the quality of template and contrast between fiducial mark and its background in original image in comparison with aerial images is low.

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