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Automatic Extraction Of Interior Orientation Data In Aerial Photography Using Image Matching Method

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Abstract

The Interior Orientation is a set of parameters that have been determined to transform the coordinates of the camera photo, that is the coordinates of the pixel leading to the coordinates of the image. This parameter is used to calibrate the camera before use so as to produce a precise measurement from an aerial photograph. This orientation parameter consists of a calibrated and equivalent camera focal length, lens distortion, principal point, fiducial mark location, camera resolution, and flatness of the focal plane. All of these parameters are attached to or contained on the camera sensor and the values of these parameters can usually be known from the camera's report page. In this work, the author wants to obtain pixel coordinates from the Fiducial Mark in the base image (Window Search) automatically, therefore a Fiducial Mark template was created which is formed from a piece of a photo image frame to determine the Fiducial Mark coordinate values from the base image (Window Search), the basis of this programming is to use the concept of photogrammetry, which uses Image Matching techniques. The Image Matching process was developed from the C ++ Language programming algorithm platform, this was done in order to speed up computational results. There are a number of techniques for doing Image Matching, in this study the authors conducted using the Normalized Cross-Correlation Image Matching. In statistics Normalized Cross-Correlation is between two random variables by determining the size of how closely the two variables are different simultaneously. Similarly, Normalized Cross-Correlation in Image Matching is a measurement by calculating the degree of similarity between two images. This level of similarity is determined by Normalized Cross-Correlation (NCC). The Least Square Image Matching method is used to increase the accuracy of the coordinates of the conjugation points.

Keywords: Interior Orientation, Fiducial Mark, Image Matching, Least Square, Normalized Cross-Correlation

1. Introduction

1.1 Sub Introduction

In the era before the digital era, the process of combining aerial photographs was carried out manually, including in the process of searching for orientation parameters. This orientation parameter consists of calibrated and equivalent camera focal lengths, lens distortion, principal point, camera resolution, flatness of the focal plane and fiducial mark location. The location value of fiducial mark is needed to find the middle value of the photo. In this research, a program is created to automatically search for the value of the orientation parameter (Fiducial Mark) with the image matching process. To find the fiducial mark value automatically needed an engineering program to find the conjugation points in two or more photos or images that overlap automatically which are the basis in digital photogrammetry. This process is usually referred to as photo matching or better known as Image Matching (Schenk, 1999; Aguoris et al, 2000).

If the overlap in the image is considered sufficient, then the same photo with the value can be described with a transformation between objects in both photos, this transformation is called Affine Transformation where the transformation is used to transform the coordinate values of a two-dimensional coordinate system into another two-dimensional coordinate system. Determination of the parameter values of a transformation is determined based on the availability of coordinate data of allied points of each two-dimensional system and the calculation technique of determining the transformation parameters. (Wolf and Dewitt, 2000).

The technique used in determining Image Matching is Normalized Cross-Correlation. In this method, the basic unit used for matching is a regular pixel-sized environment. The position of a given pattern is determined by the pixel comparison of the image with the given pattern which contains the desired pattern. For the position (m, n) of the patch template to be shifted towards the x and y directions of the search window, comparisons are calculated over the template area for each position (m, n) against the position (x, y) of the window search (Fusiello, Roberto, and Trucco, 2000)

2.1 Image Processing

In general, based on a combination of colors in pixels, the image is divided into three types namely RGB image, grayscale image, and binary image.. Each color channel has a pixel intensity value with a bit depth of 8 bits which means it has a color variation of 28 degrees (0 to 255). In the red channel, the perfect red color is represented by the value 255 and perfect black with the value of 0. In the green channel, the perfect green color is represented by the value of 255 and the perfect black with the value of 0. Likewise on the blue channel, the perfect blue color is represented by the value 255 and perfect black with a value of 0. (Ratri Dwi Atmaja, et al, 2016)

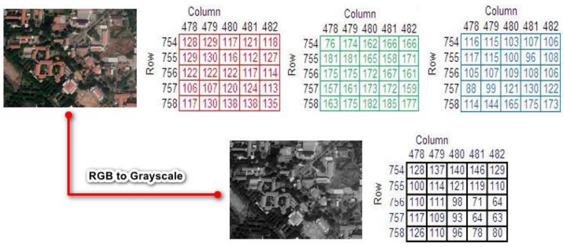

Figure 1. Conversion RGB to Grayscale (Source : Pantimena Leo, 2012)

Grayscale image is an image whose pixel intensity values are based on gray degrees. In 8-bit grayscale images, degrees of black to white are divided into 256 degrees of gray where perfect white is represented by a value of 255 and perfect black with a value of 0. RGB images can be converted to grayscale images. The equation commonly used to convert a 24-bit RGB color image to an 8-bit grayscale image is 0.2989*R+0.5870*G+0.1140*B so the conversion process produces a grayscale image that only has one color channel. (Nilima Kulkarni, 2012)

2.2 Image Matching

In general, Image Matching (also called Image Correlation) is based on checking and matching the gray level of a small part (Template Patch) of each stereopair photo, or matching the Image Patch of one photo with an Image Template. Matching may be on a pixel-by-pixel basis (Area Based Matching) or by checking and matching individual features of the Image Patch (Feature-Based Matching). Regardless of the methodology used, the most important Image Matching applications are: automatic inner and outer orientation of an image; automatic DTM manufacturing from stereo photography; and feature extraction in three dimensions such as roads, buildings, and natural boundaries. Finding the conjugation points in two or more overlapping photos automatically is the basis in digital photogrammetry.

2. Methodology

Gruen (1985) studies that if overlapping is considered sufficient, then in the same photograph the value can be described by a transformation between objects in the two photographs. In this Transformation there are 8 parameters and can be approached using Affine Transformation (6 parameters). This approach is to equate accuracy to reach subpixels. Some photo matching techniques are image-based matching, feature-based matching, and symbolic matching (Schenk, 1999; Wolf and Dewitt, 2000; Potuckova, 2004; Leica Geosystems, 2006). The relationship between each method and its entities is shown in the following table :

Table 1. Image Matching Technique.

Image Matching Method	Photo Matching Calculation Techniques	Entity
Area-based	Normalized Cross-Correlation, Least Square Matching	Gray level
Feature-based	Cost function	Point, edge, area

2.3 Image Matching

Gray value is an entity from an area-based method. The patch image is taken from the first photo which is then referred to as a template, and will be searched for in the second photo. Templates are usually mxn pixel in size, or m = n. The center of the template is at the center pixel of the template size, so the template is usually an odd size. The correlation value between the template and matching window is calculated to obtain the position of the object in the second photo (window search). To avoid mismatch, the position in the search window must be determined more thoroughly in this method. When working with stereo photos, the principle of epipolar line can also be applied.

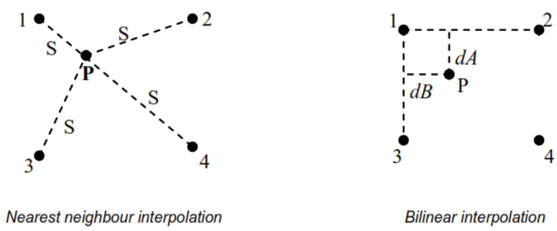

Figure 2. Nearest Neighbor and Bilinear Interpolation

Epipolar line is an intersection of epipolar plane and image plane. The epipolar plane is obtained from the projections O1, O2 and point P objects. Therefore, the conjugation points P 'and P "are assumed to be the relationship between epipolar lines e' and e". So thatmatching along the epipolar line is easier, then photos can be transformed in advance or called photo normalization (Potuckova, 2004).

2.3 Cross-Correlation Coefficient (CCC)

In statistics, the Cross-Correlation Coefficient between two random variables is a measure of how closely the two variables differ simultaneously. Similarly, Cross-Correlation Coefficient in Image Matching is a measurement of the degree of similarity between two images. This level of similarity is determined by the Cross-Correlation Coefficient (CCC) which is defined as ρ in the equation below :

$$\rho = \frac{\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}[(g_T(x_i,y_i)-\overline{g_T})(g_M(x_i,y_i)-\overline{g_M}]}{n.m-1}}{\sqrt{\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}[(g_T(x_i,y_i)-\overline{g_T})^2]}{n.m-1}}\sqrt{\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}[(g_M(x_i,y_i)-\overline{g_M})^2]}{n.m-1}}} \quad (1)$$

Cross-Correlation Coefficient (CCC), ρ, is calculated by sliding the template up. The search area from left to right and from top to bottom, as in Figure 2.2 the resulting CCC is calculated based on equation (2.2) determined for the pixel in the middle of the window. This shows the degree of compatibility between the template and the point in the image. Because NCC is actually a statistical correlation coefficient, its value, which ranges between -1 and 1, will then be interpreted following the statistical definition as follows:

$$\text{CCC} = \begin{cases} 1 & \text{(Identical image)} \\ 0 & \text{(These two images are not matched)} \\ -1 & \text{(Inverse matched = negative image)} \end{cases}$$

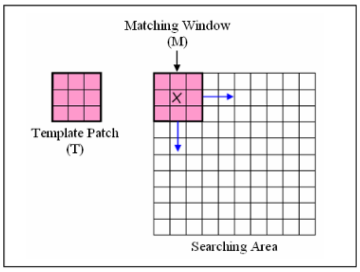

Figure 3. Calculation of CCC

2.4 Cross-Correlation Coefficient (CCC)

Normalized Cross-Correlation is one of the measurements of the conjugation point used in photogrammetry. The principle of Normalized Cross-Correlation is to look for pairs of pixel dots between the first photo and photo pairs / second photos. In the first photo the target window is determined (template)containing the pixel dots the partner will look for in the second photo. In the second photo, the search area is determined (window search) which has a larger size than the target area(template). In the region inquired(window search) / sub-region (matching window) is formed with the same size as Window / target area (template).

Matching window it's moving (moving window) with increment 1 pixel along each row and column in the search area (window search). The correlation value (r) between template and matching was calculated window. Correlation values between two groups of gray value data are calculated based on mathematical formulas in the following equation (Mitchell and Pilgrim, 1987; Schenk, 1999; Wolf and Dewitt, 2000; Campbell et al., 2008)

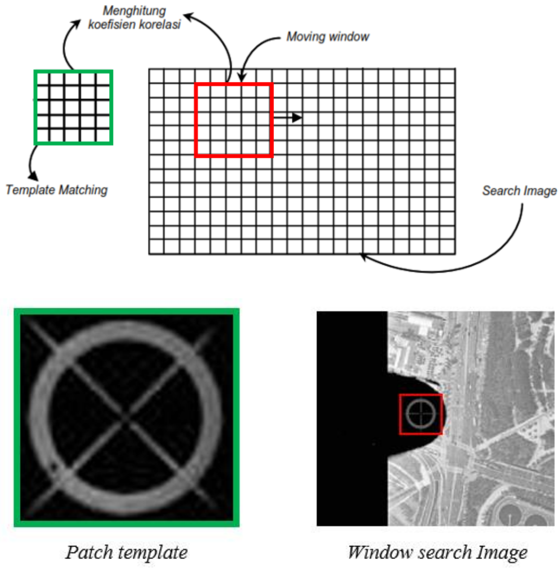

Figure 4. Calculation of CCC

If in the left photo (Figure 3) an object is determined as a reference point of search, the human eye (operator) will easily recognize and find the object in the right photo. Not so in the digital correlation process. The computer must determine the object in the right photo by observing a set of gray values as illustrated in Figure 5. The variation of pixel values in the photo is influenced by several factors, among others, the quality and quantity of pixel values that make up the object.

2.5 Least Square Adjustment

Least Square Adjustment is a statistical technique used to estimate unknown parameters combined with a solution wherein the technique can also minimize the error value of the solution itself. In the photogrammetric technique the Least Square Adjustment method is used for the process including:

1. Estimating or leveling the orientation orientation parameter.
2. Estimating the value of Object Space points (X, Y, and Z) and their accuracy values.
3. Estimating and leveling the value of the Orientation parameter.
4. Minimize and distribute data errors through the observation network.

Approach Least Squareneeded for the iteration process until a solution is obtained. A solution is obtained when the residual or error value contained in a data is minimized. For a group of observations with the same weight, the main requirements must be imposed for adjustment Least Squareis that the number of residual squares is minimized. Furthermore, in the form of an equation the Least Square Adjustment's main requirements are stated as (Wolf, 2000):

2.6 Flowchart Diagram

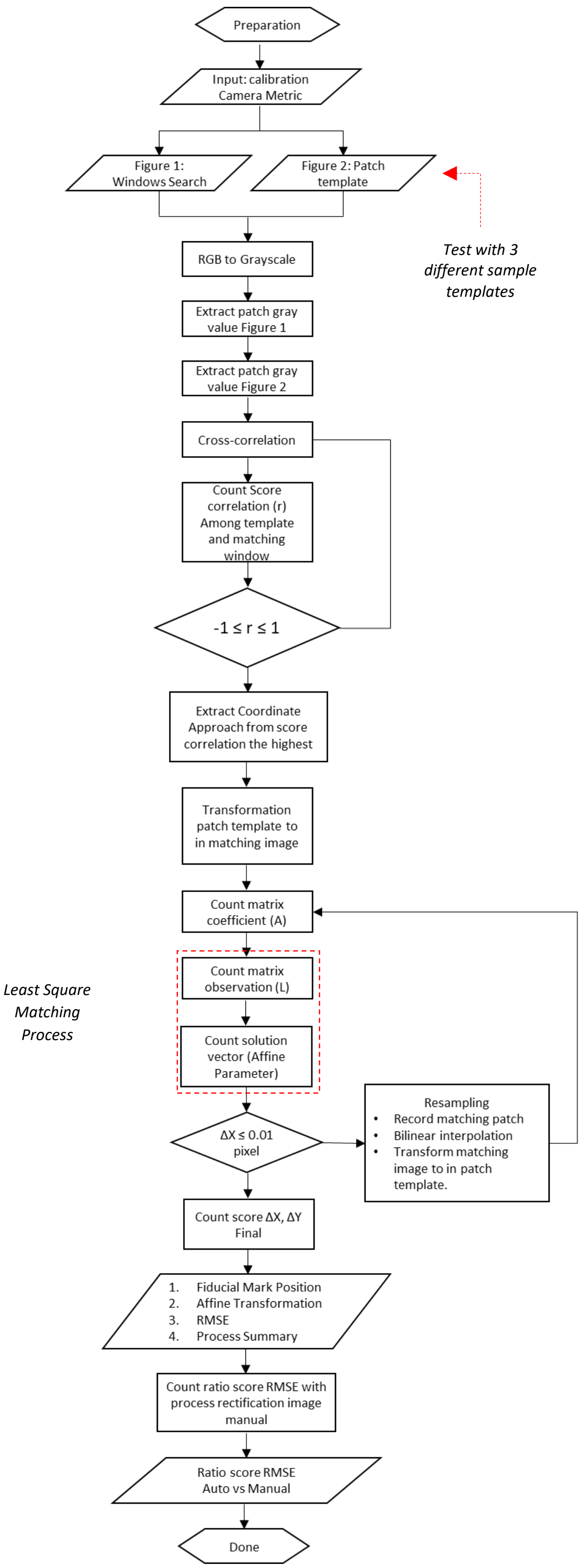

Figure 5. Flowchart diagram

3. Results and Discussion

3.1 Computing Image Matching Method

In the study discussed this is the creation of an automatic program to find the location of the Fiducial Mark coordinates identified by using the Area Based Matching method with the calculation technique using Normalized Cross-Correlation (NCC) to get the approach value, then it will be followed by another calculation technique, namely Least Squares Matching (LSM). The LSM technique perfects the search for conjugate points to achieve sub-pixel accuracy.

Below is a comparison of the value of the calculation of the process in computing that is done automatically using Fiducial Mark Finder software with the method (Normalized Cross-Correlation and Least Square Matching) compared with the results of Least Square Adjustment which is calculated manually with Ms. Excel. This count uses variables from 3 different templates.

Figure 6. Variable 3 Patch template

Table 2. Summary of the RMSE Computing Results.

Image Matching	*Template 1*		*Template 2*		*Template 1*	
General Information						
Dimension	**W**	**H**	**W**	**H**	**W**	**H**
Base Image	5738	5644	5738	5644	5738	5644
Template	50	50	50	50	50	50
Automatic Data Accuracy						
Coordinate	**X**	**Y**	**X**	**Y**	**X**	**Y**
RMSE	0,0121	0,0023	0,0172	0,0096	0,0109	0,0023
Average RMSE	0,0072		0,0134		0,0066	
Computation						
Time of Process	30		30		29	
Correlation Operation	346.034.176,00		346.034.176,00		346.034.176,00	

3.2 Affine Parameter Computing Results

From the computation results of the three Variable Templates below, produce an affine transformation parameter value that is almost uniform in value, because the rotational, translational, and dilated values of each template have the same pixel value arrangement, only differing in the angle of rotation of the image, but not too influential to the results significant

Table 3. Affine Parameter Computing Results

Parameter	Affine Transformation Count		
	Template 1	*Template 2*	*Template 3*
a11	0.041992	0.041890	0.041992
a12	0,000146	0,000143	0,000143
a21	0,000149	0,000146	0,000149
a22	-0.041986	-0.041984	-0.041986
Xt	-120.179611	-120.17421	-120.239861
Yt	116.904465	116.909943	116.862267

3.3 Cross-Correlation Coefficient

Normalized Cross-Correlation (NCC), used for the 2D version, is routinely encountered in the Image Matching algorithm, as in this study the correlation results are obtained between the Patch Template and Window Search to find the Fiducial Mark coordinate values. The following are the results of the experiments of the three different Variable Templates so that a suitable search scenario is obtained by generating the Cross-Correlation Coefficient values as follows

Table 4. CCC Computing Results

Automatic Fiducial Mark Coordinate								
X (Pixel)	Y (Pixel)	CCC	X (Pixel)	Y (Pixel)	CCC	X (Pixel)	Y (Pixel)	CCC
337,000	261,000	0891	337,000	261,000	0,922	338,000	260,000	0.771
2862,000	127,000	0,593	2862,000	127,000	0,596	2863,000	126,000	0.809
5385,000	279,000	0,999	5385,000	279,000	0899	5387,000	278,000	0.791
185,000	2785,000	0770	185,000	2785,000	0,721	187,000	2784,000	0903
5519,000	2804,000	0782	5520,000	2804,000	0,787	5521,000	2803,000	0.999
319,000	5310,000	0,955	319,000	5311,000	0,872	321,000	5309,000	0.766
2843,000	5462,000	0743	2844,000	5462,000	0,762	2845,000	5461,000	0.914
5368,000	5328,000	0899	5368,000	5328,000	0,999	5369,000	5327,000	0789

3.4 Comparison of Pixel Coordinate Values

The results below are a comparison of the photo coordinate values from the Fiducial Mark and the error tolerance value (RMSE) which is calculated based on data that is considered to be correct, namely the metric camera calibration report data issued by the United States Department of the Interior USGS

Table 4. Comparison of Pixel Coordinate Values

FD	DATA USGS		MANUAL		IMAGE MATCHING					
	Data Kalibrasi		Koordinat LSA		Koordinat TMP 1		Koordinat TMP 2		Koordinat TMP 3	
	X (mm)	Y (mm)	X' (mm)	Y' (mm)	X_1 (mm)	Y_1 (mm)	X_2 (mm)	Y_2 (mm)	X_3 (mm)	Y_3 (mm)
1	-105.994	105.998	-105.998	106.010	-105.99	105.996	-105.986	106.002	-106.009	105.996
2	0.001	111.995	0.012	111.989	0.021	111.999	0.018	111.997	0.002	111.999
3	106.001	105.994	106.004	105.985	105.989	105.993	105.979	105.985	106.012	105.993
4	-111.996	0.003	-112.007	0.017	-112.005	0.001	-112.008	0.013	-111.989	0.001
5	112.000	-0.002	111.991	-0.009	111.984	-0.002	112.008	-0.004	112.000	-0.002
6	-106.002	-105.998	-105.997	-106.030	-106.01	-105.995	-106.020	-106.018	-106.001	-105.995
7	-0.005	-111.998	0.004	-111.981	0.001	-112	0.025	-111.988	0.009	-112.000
8	105.997	-105.998	105.993	-105.988	106.012	-105.998	105.987	-105.993	105.978	-105.998
RMSE	0.000	0.000	0.008	0.015	0.012	0.002	0.017	0.010	0.011	0.002
$\overline{RMSE}$	0.0000		0.0116		0.0072		0.0134		0.0066	

3.5 Axis Difference Value Comparison Chart

The results below are comparison graphs of the value comparison results ΔX which is calculated from the reduction in the X-Axis value of the Calibration Data coordinates metric cameras issued by the United States Department of the Interior USGS on this result obtained a similar trend

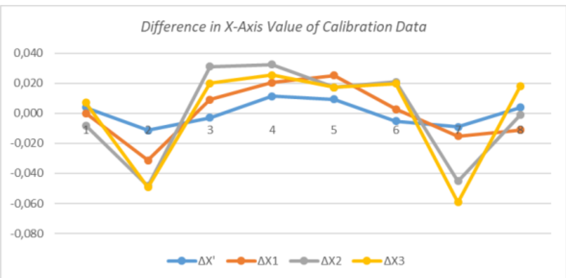

Figure 7. X-Axis Value Comparison Chart

Comparison of ΔY calculated from the reduction of the Y-Axis value in the coordinates of the Metric camera calibration data issued by the United States Department of the Interior USGS on this result shows almost the same trend

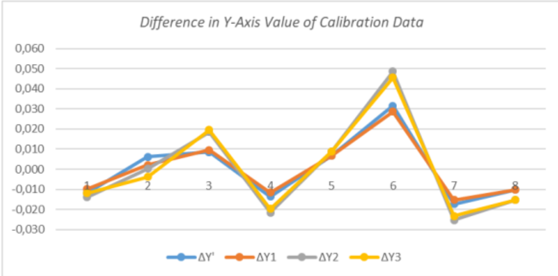

Figure 8. Y-Axis Value Comparison Chart

3. Results and Discussion

Automatic measurement in digital photographs is a basic procedure in photogrammetry. The Normalized Cross-Correlation (NCC) method with the Area Based Matching technique is precisely used in the computational method to automatically determine the Fiducial Mark value. Based on the comparison of the RMSE values of the 3 Patch Variable Templates, namely (Template 1, Template 2, Template 3) with the results of rectification manually, the Image Matching Template 3 results are more accurate than the other three variables with the RMSE value = 0.0066. RMSE accuracy of the results of manual rectification depends on the operator in searching for pixel values, because the results of the manual rectification RMSE are more accurate than the Image Matching Template 2. It is possible that the manual rectification method can get better accuracy if a bundle iteration process is performed. The computational speed in the Image Matching process is very good compared to the manual rectification process which is relatively longer.

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