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Procedures for Registering POLDER Airborne Simulated Multiangular Images*

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Abstract Multiangular imagery is an important way of obtaining multiangular remotely-sensed data. Before multiangular data can be used for analysis, it is important to register these data. Through registration, the same area can be identified from multiangular images. One of the problem in multiangular image registration is brightness variation due to differences in viewing angle, bi-directional reflectance variation and atmospheric scattering.

In this paper, a series processing of registration for multiangular images will be described. It includes pre-processing and hierarchical brightness-based registration algorithm. In order to remove the brightness differences between two images with large angle, we use an advanced template matching method which is not related to brightness mean to register images. Texture invariation will be considered. Along the viewing angle increasement direction, sequence registration can improve accuracy of large angle image registration. Finally, registration images were obtained by using local adaptive geometric correction.

We use POLDER airborne simulated multiangular images which were provided by CNES of France and have obtained more than 30 differential angle registered data of rice and wheat, etc.

Key words Multiangular, Image registration.

1 INTRODUCTION

The central problem of image registration as it is known is how to efficiently find the correspondence between the two or more images taken at different viewing points, different times or different sensors. Computing correlation or sum of squared differences (SSD) is a basic technique to registration. It lies in selecting an appropriate window size. The window size must be large enough to include enough intensity. Variation for reliable matching, but small enough to avoid the effects of projective distortion. In multiangular approach, another problem is the variations of intensity of the same ground target. This may be due to changes caused by a sensor and its position and viewpoint. Although an intensity transformation is needed before matching, in practice it is impossible to determine the necessary processing since it requires knowing the reflectance proportion of the physical objects in the scene and their shape and distance from sensor, and hence they are difficult to model effectively.

According to the correspondence, it is easy to find the translational, rotational and scaling offset between two images, such that the images can be aligned correctly. But registration becomes even more difficult if the images are less of significant features or the overlap between the two images is small.

In this paper, we developed an improved multiangular image registration method.

2 IMAGE REGISTRATION METHOD

The image registration method can be divided into two classes: brightness-based and feature-based

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(sometimes brightness-based method is called area-based method). Both classes of techniques have advantages and disadvantages that depends on the task domain and the registration accuracy required.

In brightness-based method, an appropriate window of one of the image is taken as the registration template. The template is then swept over the other image and a similarity is measured for finding the optimal registration point. The normalized cross-correlation of the two images is computed to determine the location where maximum occurs. Although the Normalized area correlation method is quite robust for image registration. Its main disadvantage is that it is computationally intensive. Using FFT algorithm, the course of computation is very complex and the expense of calculation remains the same. The sum of Absolute Difference Method is to subtract the template from the two images. Though SADM is more efficient, it is sensitive to the variations of illumination. In presently research, the adaptive window can be used to find the corresponding point.

However, for the complex scenes, feature-based techniques appear to provide more accurate information by some feature extraction process and prominent features are extracted. The correspondence between the features of the two images will determine the registration points. The features include points, line segments and areas. Typical point features that are used are corner, line intersections, points of locally maximum curvature on contour lines, centers of windows having locally maximum curvature, and centers of gravity of closed-boundary regions. The advantages of feature-based method is that features are likely to be uniquely found in both images and more tolerant of local distortions. The attempt finding corner directly or gray level images was developed by some papers[1,2]. Other method to detect corner exist, such as modeling the local gray level function around a corner point with additive Gaussion noise and finding an optimal function representing the corner detector which when convoluted with the gray level function yields a maximum at the corner point. A clustering approach to match image feature between the image was used by paper[3]. Image features may be edge elements or other edge vectors, which are obtained through an external process. All possible pairs of matches are detected. A consistent set of matching is detected by examing the cluster space and closing the mapping. Kottke used intensity and position as the original vectors to cluster[4]. After clustering, displacement estimates are obtained by matching the cluster centers between the two features using cluster features such as position, intensity, shape and average gray-scale difference.

Goshtasby used normalized invariant moments to match images using a rotationally invariant template[5]. At first, image was scanned and the zeroth-order moment was used to find possible matching points. Then the best match was determined by using second and third-order moments[6]. proposed another method using points laying on the convex hull of a set. Points along the edges of sets are extracted by selecting points that fall on the convex hull of the set. The point matching of two point sets was performed by using a subset of each set. However, incorrect matches may result since the convex hull boundary points may differ.

Another point matching registration method is to match the centers of gravity of the closed regions. Registration is then obtained by a least squares criterion[7]. Several efficient forms of registration mapping was developed by Goshtasby.

Present approach to locating feature points is based on a Gabor wavelet model for detecting local curvature discontinuities[8]. The wavelet decomposition of an image is performed in a multi-resolution fashion and is similar to a quadrature mirror filters decomposition with the low-pass filter L and its mirror filters decomposition with the high-pass filter H; The two images LH and HL of decomposition images contain the most significant features. The features called "maxima of the wavelet coefficients" can be used in the registration process. The global transformation over the whole image was computed instead of matching the reference points locally one by one. That algorithm has been implemented in parallel. However, one of the problems of feature—based method is that the success of a method depends on the robustness of the feature extraction process.

3 MULTIANGULAR IMAGES REGISTRATION

Gray—level corner detection

The corner can be determined by fitting a function of two spatial variables to gray level values in the image. The function is a polynomial of low degree, which fits the gray—level data in a small local neighborhood with minimal sum of squared errors.

We suppose a function g(x, y) to the gray—level in a picture neighborhood. Let $\theta(x, y)$ be the gradient direction given by

$$tg\theta = g_y / g_x \quad (1)$$

at any point (x, y).

The partial deviation of θ are:

$$\theta_x = \frac{\partial\theta}{\partial x} = \frac{\partial\theta}{\partial z} \cdot \frac{\partial Z}{\partial x} = \frac{g_{xy} g_x - g_{xx} g_y}{g_x^2 + g_y^2} \quad (2)$$

$$\theta_y = \frac{\partial\theta}{\partial y} = \frac{\partial\theta}{\partial z} \cdot \frac{\partial Z}{\partial y} = \frac{g_{yy} g_x - g_{xy} g_y}{g_x^2 + g_y^2} \quad (3)$$

where, $Z = g_y / g_x$;

Because the gradient vector (g_x, g_y) is directed across the edge, so the vector $(-g_y, g_x)^T$ is directed along the edge. The change vector gradient direction vector (θ_x, θ_y) along the edge represent the change of direction angle along the edge direction. See Fig. 1.

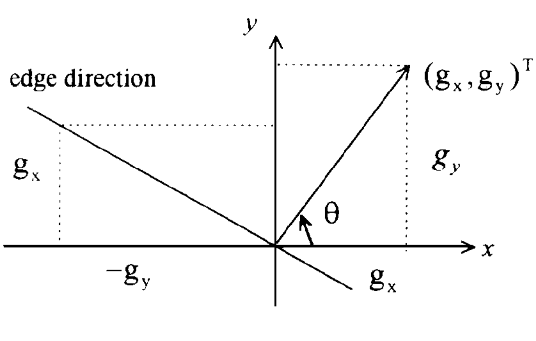

Fig. 1 Gradient direction demostration

The projecting value are:

$\theta_y \cdot \cos\theta$ along post direction of the edge.

$\theta_x \cdot \sin\theta$ along negative direction of the edge.

The magnitude in total is $\theta_y \cdot \cos\theta - \theta_x \cdot \sin\theta$. See Fig. 2.

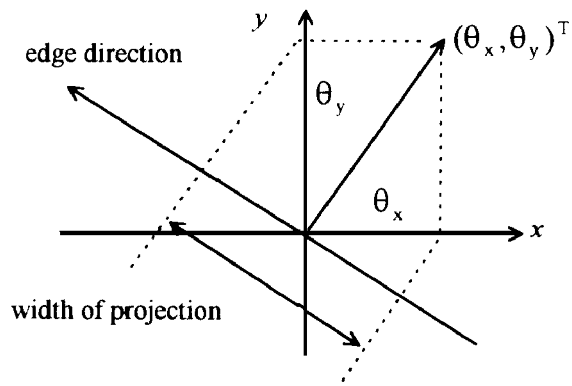

Fig. 2 Magnitude demostration

The local gradient magnitude shows the possibility of the edge. So we can define the corner by multiplying the projection value and gradient magnitude.

That is:

$$K = (-\theta_x \sin\theta + \theta_y \cos\theta)(g_x^2 + g_y^2)^{1/2} \quad (4)$$

where $\sin\theta = g_y / (g_x^2 + g_y^2)^{1/2}$

$\cos\theta = g_y / (g_x^2 + g_y^2)^{1/2}$

then:

$$K = \left(-\theta_x \cdot \frac{g_y}{(g_x^2 + g_y^2)^{1/2}} + \theta_y \cdot \frac{g_x}{(g_x^2 + g_y^2)^{1/2}}\right)(g_x^2 + g_y^2)^{1/2}$$

$$= -\theta_x g_y + \theta_y g_x$$

$$= \frac{-g_{yx} g_x g_y + g_{xx} g_y^2 + g_{yy} g_x^2 - g_{xy} g_x g_y}{g_x^2 + g_y^2}$$

$$= \frac{g_{xx} g_y^2 + g_{yy} g_x^2 - 2 g_{yy} g_x g_y}{g_x^2 + g_y^2} \quad (5)$$

The more bigger the parameter k is, the more possibility the corners occur. If there is noise to affect the accuracy of corner detecting, it can be solved by appropriately enlarge the size of the window.

Initial matching

The image registration is achieved by using a coarse to fine matching strategy. The initial match is performed on the lowest resolution images. The correspondence is determined by the best matching between feature points in the two frames. For large shift, a probability relaxation algorithm to match the feature points is necessary. The initial shift then can be calculated.

Matching criterion refinement

Though the fast algorithm-sequence similarly detection algorithm (SSDA) can be selected for point matching, its disadvantage is visible. The variation of intensity of the same ground target make it very difficult to calculate the correlation of the two images. So we try to use local adaptive filter to enhance the matching window of the image.

$$f'(x,y) = M_d + \frac{\sigma_d}{\sigma_L(x,y)}[f(x,y) - M_L(x,y)] \quad (6)$$

where, M_L is the local mean of the image, $\sigma_L(x,y)$ is the standard deviation of the image, M_d is the mean of template, σ_d is the standard deviation of the template.

After fitting the image, the matching will perform based on the sequence similarity detection algorithm (SSDA). The absolute error of every pixel is added up by:

$$E(m,n) = \sum_j \sum_k |f_1(x,y) - f_2(j+m, k+n)| \quad (7)$$

the corresponding points will be determined at the place where the biggest number of E occurs.

The hierarchical correlation method fit into the pyramid architectures that have been proposed for image processing[9]. The hierarchical matching technique described here overcomes both of these problems. First, the matching is done initially based on the larger structures in the images because they become prominent at low frequencies. This overcomes the problems due to high frequency textures. Secondly, the coarse-fine strategy restricts the small search areas at each level significantly reducing the computational cost. From the top of the structure tower to the bottom, though the hierarchical operation, we can obtain the accurate corresponding points between the original image step by step.

Our matching algorithm is summarized as follows:

Step 1: • Extracting feature points for each frame
• Doing matching between two frames
• Calculating the large shift between the two frames and using it as the initial displacement

Step 2: • Reducing the image size to that of the lowest resolution layer
• Doing initial matching to determine the corresponding points

Step 3: • Reducing the image resolution corresponding to the current layer of the matching hierarchy
• Magnifying the coordinates of the feature points corresponding to the resolution of the current layer
• Doing fine matching to obtain the corresponding relationship

Step 4: • If the current level is at the highest resolution, then stop
• Increasing the image resolution
• Go to Step 3

Geometric correction

For obtaining the registration image, the corresponding points are used to determine a transformation function which maps the rest of the point in the images.

We use the surface splines[10] for the surface fitting:

$$X(x,y) = a_0 + a_1x + a_2y + \sum_{i=1}^{n} F_i r_i^2 \ln r_i^2 \quad (8)$$

where n is the number of control points,

$$r_i^2 = (x - x_i)^2 + (y - y_i)^2;$$

$Y(x,y)$ is determined similarly.

The local weighted sum of polynomials is defined as follows:

$$X(x,y) = \frac{\sum_{i=1}^{n} W\left(\frac{\sqrt{(x-x_i)^2 + (y-y_i)^2}}{R_n}\right) \cdot P_i(x,y)}{\sum_{i=1}^{n} W\left(\frac{\sqrt{(x-x_i)^2 + (y-y_i)^2}}{R_n}\right)} \quad (9)$$

where $W_i(R) = 1 - 3R^2 + 2R^3$

$W_i(R) = 0$

$$R = \frac{\sqrt{(x-x_i)^2 + (y-y_i)^2}}{R_n}$$

R_n is the distance of point (x_i, y_i) from its $(n-1)$th nearest control point in the reference image.

4 EXPERIMENT

We first test our method on POLDER airborne simulated data which was provided by CNES. The input image size is 384 * 288.

5 CONCLUSION

A fast and robust registration algorithm has been presented. We have been obtained satisfactory nultiangualr corresponding data for several images.

The future research will focus on :

• Determining the optimum template to be used to register texture images with significant rotation.

• Extracting the method to produce sub-pixel accuracy.

• Exploring methods of small computational cost.

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机载模拟POLDER多角度图象配准

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摘　要　多角度成象对于获取多角度遥感数据是非常重要的。在对多角度数据进行分析之前，首先要对多角度图象进行配准。经过配准，可以识别出相同的地面目标。在配准过程中，一个主要的困难是由于观察角度的不同、双向反射变化及大气的影响造成的图象灰度变化。如何解决灰度变化的影响关系到图象的配准精度。

我们在该文中介绍一种多角度图象配准过程，包括预处理、基于层次结构的图象灰度相关配准。为了去掉大角度造成的灰度变化，我们用改进的模板匹配进行配准。这种方法的优点是与配准模板灰度均值无关，只与灰度变化程度有关。配准过程中也同时考虑到纹理的变化。整个配准过程是沿着观测角度增大的方向进行的序列图象配准，以提高大角度图象配准精度。最后，图象的纠正采用局部自适应几何纠正以获得较满意的结果。

我们用法国CNES提供的POLDER飞机模拟多角度图象进行配准，并提取了小麦和水稻等植被的多角度信息。

关键词　多角度，图象配准