Image Registration Improvement Based-on FFT Techniques with the Affine Transform Estimation

Sompong WISETPHANICHKIJ, Sanchaiya PASOMKUSOLSIL, Kobchai DEJHAN, Fusak CHEEVASUVIT, Somsak MITATHA and Napat SRA-IUM
Faculty of Engineering and Research Center for Communication and Information Technology,
King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok 10520, Thailand.
Tel: 66-2-3264238, 66-2-3264242, Fax : 66-2-3264554
Email: kobchai@telecom.kmitl.ac.th

Vinai VORRAWAT
National Research Council of Thailand (NRCT)

Chanchai PIENVIJARNPONG
Geo-Informatics and Space Technology Development Agency (GISTDA), Thailand.

Abstract

New Image registration techniques are developed for determining geometric distortions between two images of the same scene. First, the properties of the Fourier transform of a two dimensional function under the affine transformation are given. As a result, techniques for the estimation of the coefficients of the distortion model using the spectral frequency information are developed. Image registration can be achieved by applying the fast Fourier transform (FFT) technique for cross correlation of misregistered imagery to determine spatial distances. The correlation results may be rather broad, making detection of the peak difficult, what can be suppressed by enhancing cross-correlation technique. Yield greatly improves the delectability and high precision of image misregistration.

Keywords: image registration, affine transforms, FFT.

1. Introduction

Image registration is a fundamental in many images processing to overlay two or more images, especially for remote sensed image application. The geometric distortion can be occurred according to many reasons that need to correct before used. The precision of geometric correction depends on the efficiency of image registration of each ground control points (GCPs). The conventional correlation technique will be poor when these two images different in detail due to noise corrupted, and sensor variation. One method to solve such problem is dividing process into two steps. First, the coarse correction serves the global image registration that models the distortion problem to be the affine transformation. The advantage of this model is invariant on FFT transformation; therefore, the scaling factor and rotation angle can be extract from log-polar coordinate and phase correlation technique that mentioned in section 2. The fine registration will be consecutively performed; sub-image set will be selected as GCPs to get the precision registration and local geometric transformation correction. In section 3, induced search images set will be generated and enhance cross-correlation method is performed to get the precision registration. Finally, the geometric transformation and interpolation will be performed to achieve the image registration.

2. Affine transform theory and its parameter estimation for coarse image registration

For many data sets regional misregistration can be represented as having the following for components: (1) scale, (2) rotation, (3) skew, and (4) displacement. Such misregistration can be completely characterized by means of the affine transformation is given by

$$\mathbf{y} = \mathbf{A}\mathbf{x} + \mathbf{t} \qquad (1)$$

$$\mathbf{y} = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix}, \mathbf{x} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}, \ \mathbf{t} = \begin{bmatrix} t_1 \\ t_2 \end{bmatrix} \text{ and } \mathbf{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$$

The usefulness of the affine model results from the fact that the misregistration can be interpreted as consisting of the geometrical distortion by a linear model, and the displacement of the coordinate systems. The Fourier transforms of these data.

$$F(\mathbf{u}) = \iint_{-\infty}^{\infty} f(\mathbf{x}) e^{(-j2\pi(\mathbf{u},\mathbf{x}))} d\mathbf{x} \qquad (2)$$

The spectral domain coordinate relation is $\mathbf{v} = (\mathbf{A}^{-1})^{\mathbf{T}}\mathbf{u}$.
The non-singular matrix A characterizes the geometrical components of the misregistration.

$$\mathbf{A}_{scal} = \begin{bmatrix} a_{11} & 0 \\ 0 & a_{22} \end{bmatrix} \quad \mathbf{A}_{rot} = \begin{bmatrix} \cos(\theta) & \sin(\theta) \\ -\sin(\theta) & \cos(\theta) \end{bmatrix}$$

For special case of the same aspect ratio ($a_{11} = a_{22} = a$), the overall distortion matrix A is some combination of these component distortions

$$\mathbf{A} = \mathbf{A}_{rot}\mathbf{A}_{scal}$$

$$\mathbf{v}_{\log-polar} = \mathbf{u}_{\log-polar} - \begin{bmatrix} \log(a) \\ \theta_0 \end{bmatrix} \qquad (3)$$

Where, $\mathbf{v}_{\log-polar} = \begin{bmatrix} \log(\rho_v) \\ \theta_v \end{bmatrix}$ is a polar representation of $\mathbf{v}$ and $\rho_v = \sqrt{v_1^2 + v_2^2}$ and $\theta_v = \tan^{-1}(v_2 / v_1)$

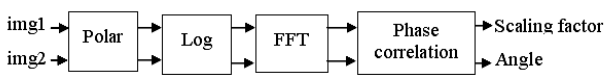


Fig.1 Rotation and scaling factor extraction by Log-Polar coordinate phase correlation

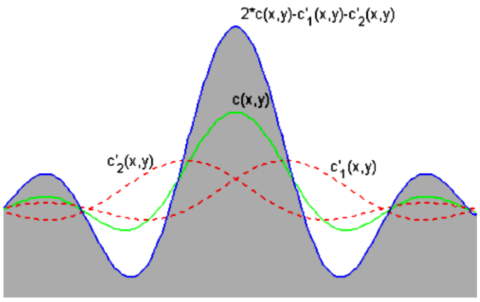


Fig.2 Enhance correlation technique

3. Enhanced cross correlation for fine image registration

If two image, f(x,y) and h(x,y), broadly correlate, the maximum peak of conventional correlation hardly detect correctly. To enhance the correlation peak, induced image set were generated to suppress the adjancent correlation. The induced image h'(x,y) should contain the same content of image h(x,y), but do not exactly same as h(x,y). Let c(x,y) is a correlation of f(x,y) and h(x,y), and c'(x,y) is a correlation of f(x,y) and induced image h'(x,y). The 1-D enhanced correlation peak can be shown in fig.2.

The induced image can be easily generated by shifting the search image to left and right for horizontal and shifting up and down for vertical correlation peak enhancement. This process is straight-forward but also drastically increasing the computation cost and do not practically use. To simplify and limit the computation cost, new induced image set h'(x,y) will be generated by flip the search image h(x,y) up-to-down and left-to-right. The enhancement scheme will be changed to

$$c_{enhanced}(x,y) = 2c(x,y) - c'_{up\to down}(x,y) - c'_{left\to right}(x,y) \tag{4}$$

$$c'_{up\to down}(x,y) = f(x,y)\circ h_{up\to down}(x,y) = \boldsymbol{F}^{-1}(F(u,v).H^{*}(u,v)_{up-down}),$$

$$c'_{left\to right}(x,y) = f(x,y)\circ h_{left\to right}(x,y) = \boldsymbol{F}^{-1}(F(u,v).H^{*}(u,v)_{left-right}),$$

$$H(u,v)_{up-down} = H(u,v).\exp\left(\frac{j\pi v}{v_{\max}}\right),$$

$$H(u,v)_{left-right} = H(u,v).\exp\left(\frac{j\pi u}{u_{\max}}\right)$$

and $\boldsymbol{F}^{-1}$ is 2-D inverse Fourier transform.

The shifted version of h(x,y) have a same the magnitude response of Fourier transform but phase response linearly increasing up to 180 degree along each orientation. Therefore, a few modify of H(u,v) is needed for generate the induced search image (H'(u,v)). The $H(-u,-v)$ can be also added to account for further enhance.

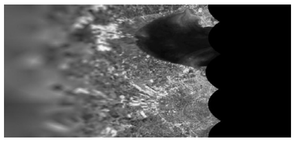
4. Test and results

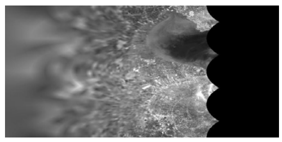
To completely the geometric correction, the first step is estimation of scaling factor and rotation angle, when coarsely assume the geometric distortion between reference image and unregistered image is affine transformation. In this study uses the SPOT image acquired on 24-11-1998 and 16-11-1998 to be a reference and unregistered image, respectively. These two images are performed sequentially as mention in section 2. The results are shown in fig.3.

After coarse registration, sub-images will be selected as a set of ground control point. Then, each GCP image will be fine registered to referenced image. Figure 4 shows three methods of correlation (only one GCP was shown). The results clearly show the proposed method (enhanced cross-correlation) efficiently improved the image registration when compare with the others method. After all GCP were registered and the geometric transformation was extracted, yield the accuracy image registration and show in fig.5.


(a) Spot 24-11-1998


(b) Spot 16-11-1998


(c)


(d)

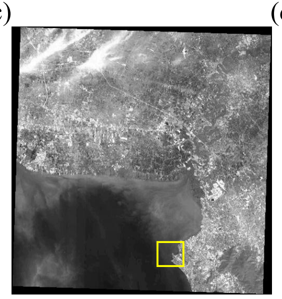
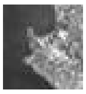
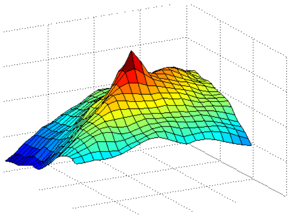

(e) Rotate angle (θ) = 1.8 and Scaling factor (a) = 1.12

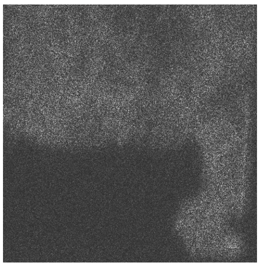
Fig.3 Multitemporal Spot image central area of Thailand
(a)Reference image (Spot image acquired 24-11-1998)
(b) Unregisted image (Spot image acquired16-11-1998)
(c) log-polar coordinate version of (a)
(d) log-polar coordinate version of (b)
(e) Coarse registered image of (b)

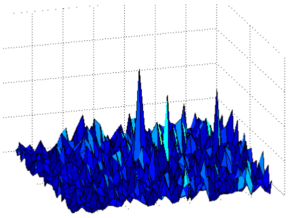


(a) Search image (GCP)

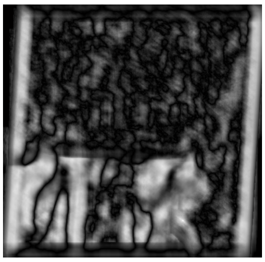


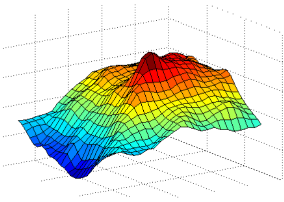
(b) Enhanced cross-correlation (c) registered area





(d) Phase correlation (e) registered area





(f) Normalize cross-correlation (g) registered area

Fig.4 Fine imager registration
(a) Selected GCP from Fig.3 (e)
(b) and (c) Enhanced cross-correlation (propose method) and its registered area
(d) and (e) Phase-correlation and its registered area
(f) and (g) Normalize cross-correlation and its registered area.

5. Conclusion

Phase correlation given the best result when search image is a part or exactly same a part of reference image, otherwise, will generate multiple correlation peak and lead to mis-registration. The pre-processing is very important and the necessary for phase correlation. For normalizing cross-correlation, the context in the search image (GCP) is a main factor to determine the correlation result. If the context broadly distributes, the correlation peak will be blurred and results a poor image registration. The proposed method (enhanced cross-correlation) utilizes the search image to suppress the adjacent and enhance the correlation peak. The efficiency trade off to computation cost.

6. Reference

[1] *W. F. Webber,* 1973. Techniques for Image Registration, IEEE Conf. on Machine Processing of Remotely Sensed Data, pp. 1B.1 - 1B.7.

[2] *R. A. Emmert* and *C .D. McGillem*, 1973. Multitemporal geometric distortion correction utilizeing the affine transform, Proc.IEEE Conf. Machine Processing of Remotely Sensed Data, pp.1B-24-1B-32.

[3] G. *Wolberg and S. Zokai,* 2000. Robust image registration using log-polar transform, Proc. on Conference on International Image Process 2000, pp. 493 -496.

[4] *B. S. Reddy* and *B. N. Chatterji*, 1996. An FFT-Based Technique for Translation, Rotation, and Scale-Invariant Image Registration, IEEE Trans. Image Processing, Vol.5, No.8.

[5] A. *Averbuch* and *Y. Keller,* 2002. FFT based image registration, Proceedings IEEE International Conference on Acoustics, Speech, and Signal Processing, (ICASSP '02), Vol.4, pp.IV-3608 -IV-3611.

Fig. 5 Completed image registration