

A New Registration Algorithm for of ASAS Multi-Angle Images

Zhu Chong-guang¹, Wang Jun¹ and Alan H. Strahler²

¹ Institute of Remote Sensing Application, Chinese Academy of Sciences Beijing 100101, P.R.China

² Center for Remote Sensing, Boston University Boston MA02215, USA

Abstract

A new area-based image registration scheme is proposed in this paper for of ASAS 0° and 30° images. It includes a series preprocessings and a resolution hierarchical relational algorithm, and a fast algorithm is used for pixel matching in every layer. The new method is not the same as the feature-based one we used in ASAS 0° and 15° image registration, and makes it possible to improve the accuracy of big angle image registration without losing the speed.

INTRODUCTION

Image registration is necessary when we compare or analyze two or more images on pixel level. The algorithms of image registration, according to the processing object, can be classified into two types, the one based on area and the one on image feature.

When we do the image registration between two images(0° and 15°) of the advanced solid-state array spectroradiometer(ASAS), we use the speedy feature-based algorithm. First the zero-cross algorithm [D.Marr & E.Hildreth, 1980] is used for edge detection. The operator of Laplacian of Gaussian (LOG) is:

$$\nabla^2 G(r) = \frac{r^2 - 2\sigma^2}{2\pi\sigma^6} \exp(-\frac{r^2}{2\sigma^2}) \quad (1)$$

Where $r^2 = x^2 + y^2$. The cross and corner points on the edge consist the selected point feature of the image which are obtained through straight line trace method. Besides, a few pairs of corresponding points are selected by man to cut down the searching area for next step — feature matching. Then, we use probability relaxation algorithm to match the points on the restriction of parallax continuity and straight line direction deviation. The last step is to produce the registration image. We use the surface splines [R.L.Harder & R.N.Desmarais, 1992] for camber fitting:

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

Where $r_i^2 = (x-x_i)^2 + (y-y_i)^2$, N is the number of control points. $Y(x,y)$ is computed so on and so forth. Furthermore, a local weighted average is used to strengthen the role of near points and effectively correct the local distortion. It is:

$$W(R_i) = \begin{cases} 1-3R_i^2 + 2R_i^3 & (0 \leq R_i \leq 1) \\ 0 & (R_i > 1) \end{cases} \quad (3)$$

Where $R_i = [(x-x_i)^2 + (y-y_i)^2]^{1/2} / R_x$, R_x is the distance between (x, y) and its nearest control point.

When there is only regional error in the images and the signal noise ratio (SNR) is high, using feature-based registration algorithm can get steep relational result and comparatively high position precision. While to the satellite images of big angle, which have serious geometric distortion and low SNR, the registration method based on edge point feature cannot be indiscriminately imitated. On the other hand, there are some questions in feature detection such as the inconsistency between geographic and geometric features and

the inconsistency of smooth binding among features. It may also happen in feature matching algorithm that corresponding feature is not exist, the description of corresponding features is not identical, the corresponding points are insufficient and resulting in an unrealistic interpolation surface, etc. Because of all these shortcomings, to the ASAS big angle image registration(0° to 30°), we choose an area-based strategy including a series preprocessings and a resolution hierarchical relational algorithm. Time is saved because of the using of a fast speed algorithm.

THE METHOD OF BIG ANGLE IMAGE REGISTRATION

Preprocessings

Removing the mean: Because the mean of an image is usually not zero, when the two images are relational compared, a direct current component will show in result. It will make the extreme value to background voltage ratio lower and the relational peak wider, and will make it difficult for the corresponding point detection and reduce the position precision. In order to diminish all these defects, we count the mean — $\overline{F(j,k)}$ of image $F(j,k)$, remove it from the image, then we get a zero mean image.

Linear filtering: This preprocessing is used to diminish random noise and enlarge the dynamic range of image grey. It can weaken the slow-changing signal and enlarge the contrast and the visibility of fine details through restraining the lower frequency component of divergent Fourier transform (DFT). The filter is 2-dimensional separable recursion filter:

$$\hat{a}_{k,l} = g_1 a_{k,l} + g_2 (a_{k,l} - \frac{\sum_{m=N_{11}}^{N_{11}+N_{12}} \sum_{n=N_{21}}^{N_{21}+N_{22}} a_{k-m,l-n}}{(N_{11} + N_{12} + 1)(N_{21} + N_{22} + 1)}) + (1-g_1)\bar{a} \quad (4)$$

Where $a_{k,l}$ is original image signal, g_1 is the coefficient for determining the weakening degree of lower frequency signal, g_2 is the const for determining the enlarging degree of fine details, N_{11} , N_{12} , N_{21} and N_{22} are the rectangle parameters fitting the detail size, \bar{a} is the estimate mean of the image after the processing.

Geometry correct: The perspective error in ASAS big angle image shouldn't be neglected, so the linear perspective transform is included to do this geometry correct. The transform expression is:

$$\begin{bmatrix} WX \\ WY \\ WZ \\ W \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} & T_{13} & T_{14} \\ T_{21} & T_{22} & T_{23} & T_{24} \\ T_{31} & T_{32} & T_{33} & T_{34} \\ T_{41} & T_{42} & T_{43} & T_{44} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad (5)$$

Take $T_{44} = 1$, distortion image and correct image on common surface, so $Z = z = 0$. Equation(5) is changed to be:

$$\begin{bmatrix} WX \\ WY \\ 0 \\ W \end{bmatrix} = \begin{bmatrix} T_1 & T_2 & 0 & T_3 \\ T_4 & T_5 & 0 & T_6 \\ 0 & 0 & 0 & 0 \\ T_7 & T_8 & 0 & T_9 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad (6)$$

According to equation(6), we get:

$$\begin{cases} X = \frac{T_1x + T_2y + T_3}{1 + T_7x + T_8y} \\ Y = \frac{T_4x + T_5y + T_6}{1 + T_7x + T_8y} \end{cases} \quad (7)$$

In order to solve the parameters $T_1 \sim T_8$ in equation(7), we need at least 4 pairs of corresponding points coordinate, and by least square method we can get the result T matrix. Through the transform shown in equation(7), the correct image with about no distortion is obtained. Doing relational comparison between this image and objective one, we can nearly maintain the registration accuracy which we get when there is no error.

Resolution hierarchical relational algorithm

In this algorithm, relational operation is in progress step by step from the rough spatial resolution to fine resolution. It includes two main process.

Resolution hierarchical structure: Take the original image f_0 as an array of $2^N \times 2^N$. In each 2×2 region, do grey average and result in image f_1 of $2^{N-1} \times 2^{N-1}$. Do the same thing to f_1 , we get f_2 of $2^{N-2} \times 2^{N-2}$. Do it so on and so forth to the last $f_k (K \leq N-1, K$ is determined according to the request roughest resolution). All these images ($f_0 \sim f_k$) consist a tower structure. (See Fig. 1)

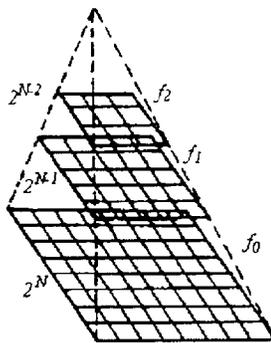


Fig. 1. Resolution hierarchical structure

To the reference and input images, we do the same thing and get two image sequences.

Hierarchical relational operation: From the top level of this tower structure, do the relational operation between the input and reference images. Because the pixels in each image, at this time, are fewer, the calculations times are not high. The relationship can be counted on every searching position, and the rough corresponding position can be determined. The second operation is on the next level of the tower. this time, we calculate the relationship only on the positions near the rough corresponding position we get last time. From the top of the structure tower to the bottom, through this hierarchical operation, we get the accurate corresponding points between the original images, and then use interpolation to form the registration image.

Sequence similarity detection algorithm(SSD): This is the fast algorithm we select for point matching on each level of the resolution tower. In the matching windows of image $f_1(j,k)$ and image $f_2(j,k)$, add up the error of every pixel:

$$\varepsilon(m,n) = \sum_j \sum_k |f_1(j,k) - f_2(j+m,k+n)| \quad (8)$$

If before all the $(J \times K)$ points in windows have been checked, the predetermined threshold has been caught, this window position can be discarded and the program goes to the next step with no checking the remainder points. If $\varepsilon(m,n)$ goes up slowly, record the number

of adding points. After all the probable matching windows under the restriction of parallax continuity have been detected, the one which has the biggest number of adding points is the corresponding point.

An improvement upon the resolution hierarchical relational algorithm is to abandon the obvious mismatched points using SSDA, and to calculate the extreme matching value among the probable windows through statistical relational algorithm(SAR). The combination of SSDA's speed and SRA's accuracy shows its advantage.

RESULT & CONCLUSION



Fig. 2. 0° original image



Fig. 3. 15° original image

Conclusion

The random noise and geometric distortion deteriorate in big angle images, the preprocessings mentioned above are necessary.

The unity of the resolution hierarchical relational algorithm on each level and the inclusion of SSDA, make the prospect of hardware realization captivating.

The solid information of topography and vegetation can be attainable after image registration of different angles.

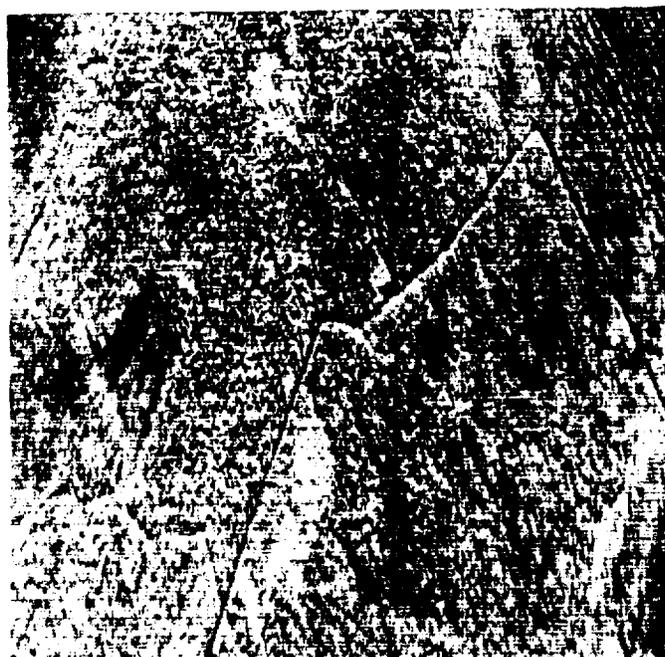


Fig. 4. 30° original image



Fig. 5. 0°-15° registration image



Fig. 6. 0°-30° registration image

REFERENCES

- [1] Burt,P.J., Anderson,C.H., Sinniger,J.O. and VanderWar,G., A Pipeline Pyramid Machine. In *Pyramidal Systems for Image Processing and Computer Vision*. 1986: pp21-39.
- [2] Gashtasby,A., Registration of Images with Geometric Distortions. *IEEE Trans. On Geoscience and Remote Sensing*. Vol.26 No.1 Jan.1988: pp60-64.
- [3] Harder,R.L. and Desmarars,R.N., Interpolation Using Surface Splines. *J.Aircraft* Vol.9 No.2 1992: pp189-191.
- [4] Li,M.X., Hierarchical Multipoint Matching. *PERS*. No.8 1991: pp1039-1048.
- [5] Marr,D. and Hildreth,E.C., Theory of Edge Detection. *Proc. Royal Soc. of London*, B207 1980: pp187-217.
- [6] Sun,Z.K. and Shen,Z.K., *Digital Image Processing and Applications*. Beijing: National Defense Industry Press. 1985: pp285-296.
- [7] Wong,R.Y., Hall,E.L. and Rouge,J., Hierarchical Search for Image Matching. *Proc. of IEEE Conf. on Decision and Control*, 1976.
- [8] Yang,Y.H. and Zhou,W.Z., *Target Tracing Methodologies*. Xi'an Electronic Technology University Press. 1992: pp85-89.

ACKNOWLEDGEMENTS

This work was partially supported by Chinese National Natural Science Foundation (49331020) and NASA (NAS5-31369).