A NEW CONTROL POINTS CONSTRAINED PIECEWISE GEOMETRIC CORRECTION METHOD FOR SERIOUSLY OBLIQUE REMOTE SENSING IMAGE

Wang Chunyuan, Zhang Ye, Chen Yushi，Gu Yanfeng

School of Electronics and Information Engineering, Harbin Institute of Technology

1. INTRODUCTION

Conventional approaches for geometric correction [1] usually dedicate only one correction model to operate the whole distorted image. In fact, with the changing of view angles and imaging paths, the imaging extent is wide and the distortions of different regions of a whole image are truly different. Conventional approaches are unsuitable to effectively correct the image acquired in the seriously oblique conditions. This paper introduces a polynomial correction system that addresses this problem based on a control points (CPs) constrained piecewise algorithm. The control points are clustered into *N* clusters where the cluster centers are selected based on the variability of spatial resolution of the oblique image. And then the partitioning positions are determined by the centroid of CPs' distribution in each cluster. The whole image is partitioned into contiguous subspaces which are respectively corrected and interpolated by different correction models. The experimental results show that the proposed correction system is significantly outperforming conventional approaches.

2. THE SUBSPACE PARTITIONING STRATEGY

Aircraft carrying the imaging sensor moves in the correspondingly low height, meaning that an image would be taken at a large angle. The spatial resolution of off-nadir image is poorer than that of nadir image reasoning by the projection extent of a detector onto the ground [2]. The geometry is shown in Fig. 1. According as the trigonometric function, the off-nadir ground resolution is given by

$$RES_{\theta} = \frac{\beta H}{\cos^2 \theta} = \frac{RES_n}{\cos^2 \theta} \tag{1}$$

Here, RES_{θ} is the off-nadir ground resolution, RES_n is the nadir ground resolution, θ is the angle from nadir.

The imaging extent is wide with a large imaging angle. The distortions of different regions of a whole image are truly different just like the quite changing resolution as discussed above. Also, the large dimensions of an image would obviously magnify the errors formed in computing the correction coefficients. Consequently, partitioning the entire image is a necessary step for a high precision correction toward the seriously distorted image.

The crucial problem for piecewise correction is how to partition the whole distorted image. The partitioning is implemented by two key steps: the selection of cluster centers and the determination of the partitioning positions.

2.1. The selection of cluster centers

This section finds the cluster centers that minimize the distortion based on the variability of spatial resolution of the oblique image. The whole image is originally partitioned into N subspaces based on the variability of spatial resolution. And then the regional centers of each original subspace are selected to be cluster centers. In Fig.2, the variability of spatial resolution and the originally partitioning method are figured. Our aim is enable each subspace to possess approximately changing rate of spatial resolution. The metric employed for partitioning is as follows

$$\theta_n = \arccos\sqrt{N\Big/\left(\frac{n}{\cos^2\theta_N}+\frac{N-n}{\cos^2\theta_0}\right)} \quad (0 \le \mathrm{n} \le \mathrm{N}) \tag{2}$$

Here, θ_0 and θ_N are boundaries of the view angles and θ_n is the location of original subspace partitioning.

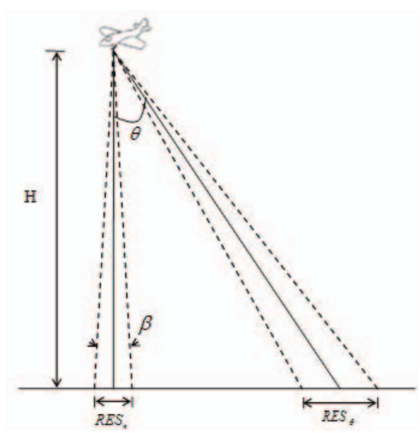


Fig.1. Spatial resolution of off-nadir and nadir

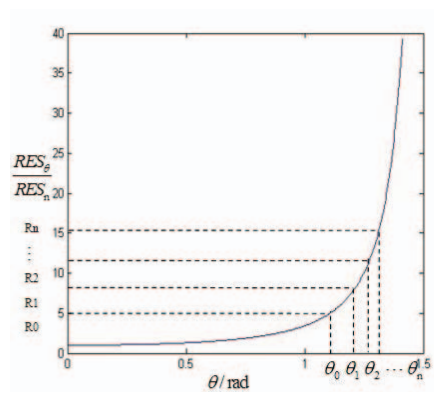


Fig.2.The original partitioning strategy

2.2. The determination of partitioning positions

The distribution of control points (CPs) is an important factor which impacts on estimating the parameters of the correction model. Based on the cluster centers selected above, the CPs are clustered into *N* cluster subspaces. Suppose that $\mathrm{P}=\{p_1, p_2, \cdots, p_l\}$ is the set of CPs of the whole image, and $c=\{c_1, c_2, \cdots, c_N\}$ is the set of cluster centers, the *i*th cluster subspace is composed by

$$\mathrm{V}(c_i)=\bigcap_{j\neq i}\{p \mid d(p_k, c_i) < d(p_k, c_j)\} \quad \text{(i=1,2,…,N)} \tag{3}$$

Where the *i*th cluster subspace is denoted by c_i and consists of all the CPs p_k that are closer to c_i than to any other cluster centers. Considered that the seriously oblique direction is the primary issue in this work, the $d(p, c_i)$ is measured by weighted Euclidean distance

$$d(p_k, c_i) = \left[(1-w)\cdot(x_p - x_c)^2 + w\cdot(y_p - y_c)^2\right]^{1/2} \quad (4)$$

Where (x_c, y_c) and (x_p, y_p) respectively are the coordinates of cluster center and CP, and w is the weight of the y axis which is assumed as the seriously oblique direction. Here, y is assigned bigger w than x.

And then the centroid of each cluster subspace can be calculated by

$$(\overline{x_n}, \overline{y_n}) = \left((\sum_{i=1}^{m} x_i)/m, (\sum_{i=1}^{m} y_i)/m \right) \quad (5)$$

Where m is the number of CPs in each cluster, and n is the nth cluster subspace.

The partitioning positions are finally identified by the bisector of the adjacent centroid along y axis. It is given by

$$\mathrm{POS_n} = \left(\overline{y_n} - \overline{y_{n-1}}\right)/2 \quad (6)$$

Here, $\overline{y_n}$ and $\overline{y_{n-1}}$ are the y coordinates of the centroids of two adjacent cluster subspaces.

3. THE PIECEWISE GEOMETRIC CORRECTION SYSTEM

Base on above techniques, the piecewise geometric correction employed the quadratic polynomial transformation which directly simulates the essentiality of image distortions. The flow of the proposed system is as follows.

(i) Sufficient CP pairs are extracted by SIFT [3] and their distribution is uniformed [4].

(ii) The whole image is partitioned into several subspaces based on section2.

(iii) Each subspace is respectively corrected and interpolated by the established different correction models.

(iv) At last, every corrected subspace is incorporated to the final corrected image.

4. EXPERIMENTAL RESULTS

The new system is tested by our simulation platform with known relevant data, so that the efficacy can be quantitatively measured. The imaging angles at the midpoint are from 15 degrees to 75 degrees for an interval of 15 degrees. Considered the CPs number and computation complexity, N is set to 3. The test points in all the experiments have the same quantity and quality to ensure the equality of experiments, the number is 12.

The partitioning is based on two metrics: resolution-based partitioning and CPs constrained partitioning. Fig. 3 shows the comparison of the correction performance among the whole image and both partitioning metrics. For an image acquired in 60 degrees, the new method results in correction root mean square errors (RMSE) having 0.5 pixel improvement comparing to the resolution -based partitioning and around 2.5 pixels improvement comparing to the traditional method. It can be inferred that the proposed partitioning method provides a more meaningful partition, resulting in more robust geometric correction. The proposed piecewise correction system is very powerful for the seriously distortions comparing with conventional whole image-based correction. For a result of an airdrome, as shown in Fig. 4, the boundaries of each subspace maintain the smoothness which depends on the high estimation accuracy of each transformation model.

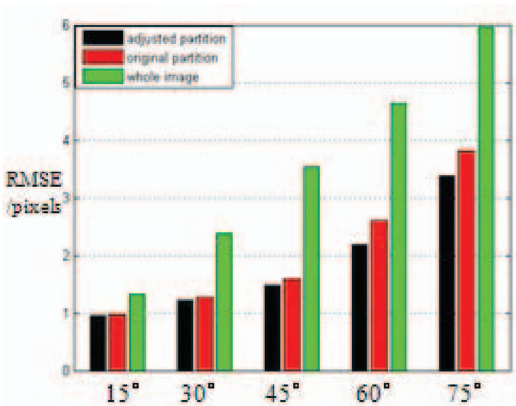
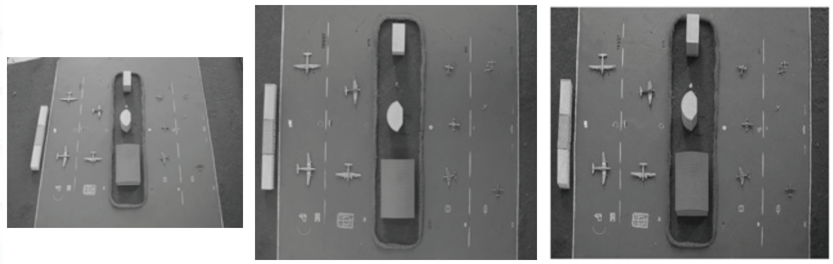


Fig.3. Performance of the proposed system



(a) Distorted image (b) Reference image (c) Corrected image

Fig.4. A correction result for an airdrome.

5. CONCLUSION

For accurately correcting the seriously distorted image, a new polynomial geometric correction system is proposed based on a CPs constrained piecewise correction algorithm. The partitioning is determined by the clustering of CPs where the cluster centers are selected based on the variability of spatial resolution of the oblique image. It is experimentally demonstrated that the piecewise polynomial correction system consistently outperforms the conventional whole image-based correction.

6. ACKNOWLEDGMENT

The authors would like to thank Dr. Andrea Vedaldi(Visual Geometry Group, Oxiford University, UK) for providing the SIFT code. This paper is supported in part by National Natural Science Foundation of China (60972143).

7. REFERENCES

[1] F. Eugenio, "Automatic satellite image georeferencing using a contour-matching approach," *IEEE transactions on geoscience and remote sensing*, vol. 41, No. 12, December 2003.

[2] Amy E. Galbraith, James Theiler, Kurtis J. Thome, and Richard W. Ziolkowski, "Resolution Enhancement of Multilook Imagery for the Multispectral Thermal Imager," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 43, no. 9, September 2005.

[3] D. Lowe, "Distinctive Image Features from Scale-Invariant Keypoints," *Int'l J. Computer Vision*, vol. 2, no. 60, pp. 91-110, 2004.

[4] K. Mikolajczyk and C. Schmid, "A Performance Evaluation of Local Descriptors," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 27, no.10, pp.1615-1630, October 2005.