Automatic Image Mosaicking

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Abstract: This paper proposed the method of creating image mosaic in automated fashion. It is well known that geometric and radiometric balance in adjacent images should be maintained in mosaicking process. The seam line to minimize geometric discontinuity was extracted using Minimum Absolute-Gray-Difference Sum considering constraint condition in search width. To maintain the radiometric balance of images acquired at different time, we utilized Match Cumulative Frequency, Match Mean and Standard Deviation and Hue Adjustment algorithm. The mosaicked image prepared by the proposed method was compared with those of commercial software. Experiments show that seam lines were extracted significantly well from roads, rivers, ridgelines etc. and Match Cumulative Frequency algorithm was performed pretty good in histogram matching

Keywords: Image Mosaic, Seam Line, Histogram Matching.

1. Introduction

Satellite image mosaicking is essential for image interpretation and analysis especially for a large area such as the Korean Peninsula. It is well known that geometric and radiometric balance in adjacent images should be maintained in mosaicking process. Although the images are already geometrically corrected, geometric discontinuity in the neighboring area has a great effect to the quality of mosaicked image. Especially, the seam line extraction using image matching algorithm is very important in case of automatic processes on image mosaicking in order to reduce manual intervention. To maintain radiometric balance, moreover, it is necessary to apply the histogram matching and image enhancement among the adjacent images (Zobrist, 1983; Shiren, 1989; Afek and Brand, 1998).

This paper presents the method of creating seamless image mosaic in automated fashion using geometrically corrected satellite images. The mosaic method is based on five major stages:

1. Determination of overlap area
2. Seam line extraction
3. Selection of master image for histogram matching
4. Histogram matching
5. Generation of mosaicked image

2. Seam Line Extraction

It is essential for creating image mosaic in automated fashion to extract automatically seam line in adjacent images. When extracting seam line, moreover, it is important to minimize geometric discontinuity in adjacent images.

In this paper, we applied Minimum Absolute-Gray-Difference Sum (Milgram, 1975; Shiren et al., 1989) algorithm among diverse methods. This algorithm is a method that minimum sum of gray values is searched continuously in a pair of overlapped images. For that, the systematic method is applied.

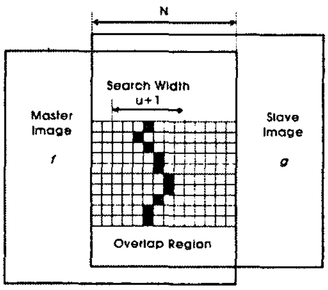


Fig. 1. Seam line extraction.

1) Overlap Area Determination

To extract seam line, the first stage is the automatic determination of overlap area in adjacent images. In this paper, on assumption that images already completed geometrically correction, the overlap area is selected by transforming master and slave images after determining the absolute coordinate of overlap area using the coordinate information of image header.

2) Seam Line Extraction

When the overlap area is selected and the shape of that is determined, the algorithm is applied according to row or column. Assuming that the gray values of the master and slave images are represented by f and g, respectively, and the overlap region is N pixels wide. As shown in figure 1, the sums of the pixels absolute grey difference in the *j-th* row over $u+1$ pixels wide search area within the overlap regions are

$$v_{j,k} = \sum_{i=-\frac{u}{2}}^{\frac{u}{2}} \left| f_{j,k+i} - g_{j,k+i} \right| \qquad (1)$$

The seam point position (j, k^*) is determined for the *j-th* row by finding the minimum value of $v_{j,k}$. The connected lines of each seam point are the seam line to minimize the geometric discontinuity.

3) Constraint Condition

Because Minimum Absolute-Gray-Difference Sum (Milgram, 1975; Shiren et al., 1989) algorithm only performs the one-dimensional search of one row or column, it can cause discontinuity between adjacent rows and columns. To reduce that, the constraint condition of search width should be added.

In this paper, after extracting seam points (j, k^*) of the first row or column, in the next row or column we don't find seam point at the entire pixels and performs the search centered on ($j+1$, k^*) within limited search width. In this case, the determination of limited search width is critical issue and we applied 1/5 of origin search width.

3. Histogram Matching

When creating image masaic, it is necessary to maintain radiometric balance by uniforming radiometric characteristic among adjacent images. This process is generally called histogram matcing.

As shown in figure 2, after extracting image of Buffer Zone which has the same that of search width, we applied three different methods such as Match Cumulative Frequency, Match Mean and Standard Deviation and Hue Adjustment algorithm to analyze the behaviors of three methods.

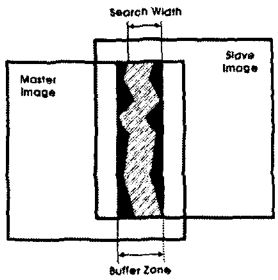


Fig. 2. Histogram matching.

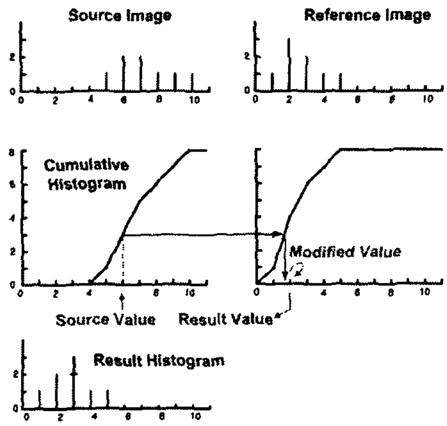


Fig. 3. Match cumulative frequency algorithm

1) Master Image Selection

Because histogram matching method is generally accomplished by statistical analysis of images, the quality of resultant image is influenced by the selection of master image. In this paper, we utilized statistical information of each image such as variance, range, mean and mode in order to select master image in more objective fashion.

2) Match Cumulative Frequency Algorithm

Match Cumulative Frequency algorithm is the method to maintain radiometric balance by uniforming cumulative histogram between master and slave images.

The cumulative histogram between reference (master) and source(slave) images are computed at first hand shown in figure 3. Then by transforming the gray value of source image into the gray value of reference image, the distribution shape of histogram could be matched between them. Since the gray value of reference image that is corresponding to the gray value of source image exists in float value, the procedure that is converting float value into integer value needs to be processed. However, this procedure might introduce some errors, but they are insignificant.

3) Match Mean and Standard Deviation Algorithm

Match Mean and Standard Deviation algorithm is the method to maintain radiometric balance by uniforming the mean and standard deviation of slave image with those of master image. Assuming that the mean and standard deviation of slave image are represented by M_g and σ_g, the gray value $g(x,y)$ of slave image should be transformed to $g'(x,y)$ in order to maintain uniform statistical value among two images.

$$g'(x,y) = \frac{\sigma_{fg}^2}{\sigma_{gg}^2}(g(x,y) - M_g) + M_f \quad (2)$$

$$\sigma_{gg}^2 = \iint (g(x,y) - M_g)^2 dxdy \quad (3)$$

$$\sigma_{fg}^2 = \iint (g(x,y) - M_g) \times (f(x,y) - M_f) dxdy \quad (4)$$

4) Hue Adjustment through Moving the Histogram

Hue Adjustment algorithm is the method to maintain radiometric balance by uniforming histogram between master and slave images, and it is similar to Match Mean and Standard Deviation algorithm. However, this algorithm doesn't utilize the statistical value such as the mean and standard deviation, only utilizes the maximum and minimum values of histogram in master and slave images. Generally, when use Hue Adjustment algorithm, the gray value $g(x,y)$ of slave image are transformed to $g'(x,y)$ using correalation.

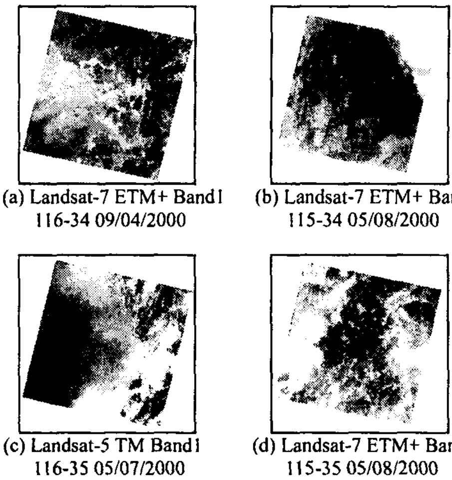
$$g'(x,y) = INT\left[(f_{\max} - f_{\max}) \times \frac{g(x,y)}{(g_{\max} - g_{\max})}\right] + (M_f - M_g) \quad (5)$$

Where, f_{max}, f_{min}, g_{max}, g_{min} means the maximum and minimum values of histogram in master and slave images, respectively.

4. Experimental Results

In order to test the performance of the proposed method, we used satellite images captured on different time and different sensors. Secondly, to analyze the suitability of seam line, we don't perform histogram matching beforehand. Thirdly, we compared the mosaic images that are created by three different histogram matching methods. Finally, we compared mosaic image generated by the proposed method with those generated by commercial software.

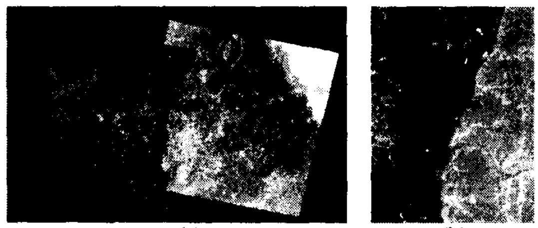
The satellite images for experiment are Landsat MSS/TM/ETM+ which are geometrically corrected. Figure 4 shows four images which are acquired different time and sensors. Figure 4 (a) is ETM+ image which is collected on Sep 4, 2000, (b) and (d) are ETM+ images on May 8, 2000, and (c) is TM image on May 7, 2000.



(a) Landsat-7 ETM+ Band1 116-34 09/04/2000
(b) Landsat-7 ETM+ Band1 115-34 05/08/2000
(c) Landsat-5 TM Band1 116-35 05/07/2000
(d) Landsat-7 ETM+ Band1 115-35 05/08/2000

Fig. 4. Original images which geometrically corrected.

Figure 5 is a mosaicked image using figure 4(a) and 4(b) which are not performed on histogram matching. Seam line is automatically created in middle of overlap area between neighbor images, specially seam line along a river is created in figure 5(b).



(a) (b)

Fig. 5. Mosaicked image which is not performed on histogram matching.

Figure 6 shows a mosaicked image which is performed on histogram matching. 6(a) is the case that is not performed histogram matching, 6(b) applied Match Cumulative Frequency algorithm, 6(c) Match Mean and Standard Deviation algorithm, and 6(d) Hue Adjustment algorithm, respectively. The results show that images with histogram matching are more uniform than image without histogram matching. Especially, when Match Cumulative Frequency Algorithm is applied, the mosaicked image shows very uniform resultant image.

Figure 7 shows the mosaicked images that are obtained using commercial software and that of proposed method. Figure 8 shows the color mosaicked image generated by the proposed method.

5. Conclusions

This paper proposed the method of creating image mosaic in automated fashion using geometrically corrected satellite images. Experiments show that seam lines were well extracted from roads, rivers, and ridgelines. The histogram matching algorithm is an appropriate method to maintain the radiometric balance of images acquired at different time.

In our limited experiments, Geomatica OrthoEngine of PCI Geomatics Inc. is best suited to mosacking among commercial software. Overall, the quality of resultant mosaicked image generated by the proposed method was quite close to that of Geomatica OrthoEngine. Even some parts of the mosaicked image are better than those of Geomatica OrthoEngine.

Acknowledgement

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References

[1] Afek, Y., Brand, A., Mosaicking of orthorectified aerial images, *Photogrammetric Engineering & Remote Sensing*, Vol. 64, No. 2, 1998.

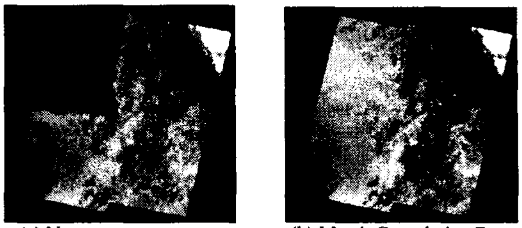
[2] Du, Y. et al., Radiometric normalization, compositing and quality control for satellite high resolution image mosaics over large area, *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 39, No. 3, 2001.

[3] Gonzalez, R. C., Woods, R. E., *Digital image processing*, Prentice Hall, 2001a.

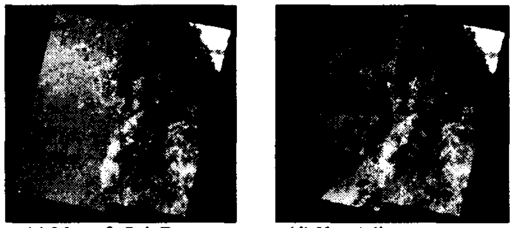
[4] Lillesand, T. M., Kiefer, R. W., *Remote sensing and image interpretation*, John Wiley & Sons, 1994.

[5] Tsai, V. J., Huang, Y., Automatic image mosaicking, *ACSM-ASPRS 2002 annual conference proceeding*, 2002.

[6] Yi, Y. et al., Hue adjustment method of large-scale image database, *International Archives of Photogrammetry and Remote Sensing*, Vol. XXXIV, Part 2, Commission II, 2002.

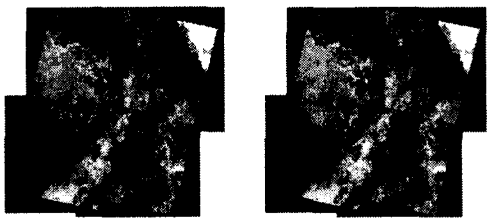


(a) None (b) Match Cumulative Freq.

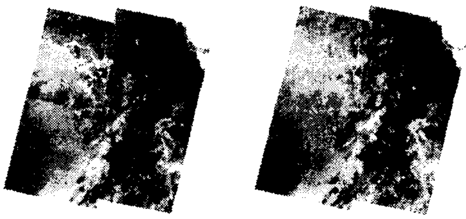


(c) Mean & Std. Dev. (d) Hue Adjustment

Fig. 6. Mosaicked image using proposed histogram matching



(a) Image analyst (b) Erdas imagine



(c) Geomatica orthoengine (d) Proposed method

Fig. 7. Mosaicked images using commercial software.

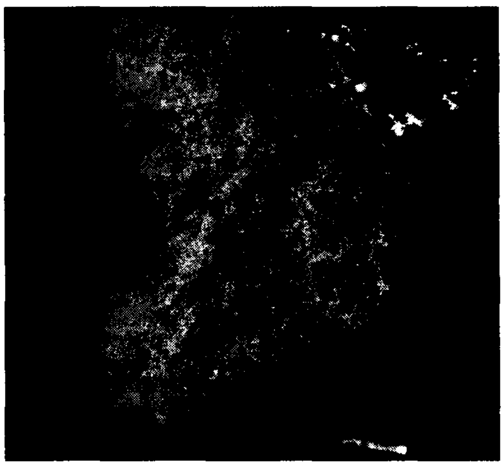


Fig. 8. Color mosaicked image.