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Images Fusing in Remote Sensing Mapping[1]

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ABSTRACT - The remote sensing images fusing is a method, which integrates multiform image data sets into a new data set by geometry matching, color transformation and other ways. During mapping the LiJiang county in YunNan province with high-resolution remote sensing image, we found that it is a good way to utilize the technique of image fusing, which includes image matching, image interpolation, edge enhancement, and imagery updating, to improve the mapping quality. After iterative experiments, we explored a new way to update and fuse based on TM image, SPOT panchromatic image and the air photos. In the fused image, various RS images information can supplement each other, so the fused image not only have abundant spectrum information, but also reserve high spatial resolution. It proves that imagery fusion is an important way to improve represent ability on map of imagery.
Keywords imagery fusing; remote sensing mapping; high-resolution remote sensing image

1. Background

The remote sensing images fusing is a method based on a lot of image processing technique, it comes forth in 1970s. When it comes to 1990s, images with different space-time resolution have been presented by different remote sensors on those multiple remote sensing satellites and have formed an image pyramid list.

The image pyramid list gives the users manifold data sources, which cover from low to high ground resolution images, from multi-spectrum to fractional spectrum. After the long-time researching, it is feasible for the technique of the fusing of multi-source data. At present, the widely used methods of data fusing mainly includes the weight-based fusing method based on pixels, IHS transformation, ratio transformation, the character fusing method based on wavelet theory, the classification fusing based on Bayes theory etc[1].

In 2000, we made the map of the Lijiang County in Yunnan province with high-resolution remote sensing image. During the procedure of mapping, we utilized the technique of data fusing, integrated the multi-info of remote sensing from different sensors in multi-lever. By these ways, the feature of man-made objects is enhanced and becomes prominent, and we also got more powerful information to identify the object, which can make the image more readable. Besides these, using the method of data fusing also reduced the cost of the remote sensing mapping and strengthened the mapping quality for visual interpretation.

After iterative experiments, we explored a way to update and fuse the data with TM image, SPOT panchromatic image and the air photos. The method is introduced in chapter 2, chapter 3 and chapter 4.

2.The registration and enhancement of different remote sensing digital image

Registration of Image is the key process before image fusing, the precision of registration will impress directly the quality of the fusing. In practice, digital relief map is identically adopted for our base map to correct TM? SPOT image and the air photo geometrically. The target of which is to make the TM? SPOT and the air photo have the unite projection and coordinate system, which will do well to the fusing of different type and time image. The method for registration of image can be summarized as following:

The geometric transformation for the coordinate of pixels. The 1st step is to build the correlation between

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the coordinate of input pixel (x, y) and its output pixel (u, v), which is the coordinate of pixel after having been transformed. By making use of each output pixel's position, we can work out the coordinate (x, y) of input point. The formula of geometric transformation can be expressed by quadratic polynomials. That is:

$$\begin{cases} x = a_{00} + a_{10}u + a_{01}v + a_{11}uv + a_{20}u^2 + a_{02}v^2 \\ y = b_{00} + b_{10}u + b_{01}v + b_{11}uv + b_{20}u^2 + b_{02}v^2 \end{cases} \quad (1)$$

To find corresponding x and y by u and v, the twelve coefficients in Eq. (1) is indispensable. To gain them, we make use of six pairs of (u, v) and (x, y) to resolve the Eq. (1) at the least.

In rectification, we made use of ground control points that are identifiable in both the distorted image and the reference map to get the coefficients in Eq. (1). But we found that six of pairs of ground control points are the least number to solve the equation. They are so inadequate that the accuracy of geometric transformation is always dissatisfying apparently. For instance, at the edge or in the region with greatly changing terrain, such as river's turning, if there is no ground control points but derived points to depend on, the transformation will get distorted image. So it's necessary to add many well-distributed ground control points to get high accuracy. After gained coefficients are put into Eq. (1), you will get each output point's corresponding x and y by performing the Eq (1).

The resampling for the digital number of each pixel. The purpose of resampling is to compute the digital number of each output pixel. Since the new locations of transformed pixels will rarely coincide with the initial position of input pixels, the new digital numbers of these pixels must be recomputed.

As you know, digital number for the transformed pixels must be interpolated from the neighborhood surrounding the input pixel, bilinear interpolation is utilized to resample for the digital number, detail method for resample is as follows:

Let (i, j), (i, j+1), (i+1,j), (i+1,j+1) denote four adjacent points surrounding the input pixel(x, y), here i and j represent the upper left-hand corner's line number and column number at the pixel grid respectively. Suppose a = x-i, ß = y-j, Draw a line through point (x,y) paralleling with x-axis, then the line must intersect with one side of the rectangle which is formed by its four adjacent points at point (i,y) and (i+1,y). Depend on the trapezoid formula:

$$\frac{f(i,j) - f(i,y)}{b} = \frac{f(i,y) - f(i,j+1)}{1-b} \quad (2)$$

We can get:

$$f(i,y) = bf(i,j+1) + (1-b)f(i,j) \quad (3)$$

Similarly, we can get:

$$f(i+1,y) = bf(i+1,j+1) + (1-b)f(i+1,j) \quad (4)$$

Then, implement the interpolation along x direction, using the side which connects f (i, y) and f (i+1,y) to determine the value of f (x, y).

$$f(x,y) = af(i+1,y) + (1-a)f(i,y) \quad (5)$$

Synthesize (3), (4), (5) and we get:

$$f(x,y) = a[bf(i+1,j+1) + (1-b)f(i+1,j)] + (1-a)[bf(i,j+1) + (1-b)f(i,j)] \quad (6)$$

The values of i and j is defined as follows:

$$\begin{cases} \text{i} = \text{Integer(x)} \\ \text{j} = \text{Integer(y)} \end{cases} \quad (7)$$

When implementing this algorithm, we can compute pixel by pixel horizontally from left to right and line by line vertically downwardly until the end of the image. Finally, all digital numbers for the transformed pixels are determined by taking a proximity-weighted average of input digital numbers from the four nearest pixel.

Edge enhancement.

The goal of edge enhancement is to improve the detectability of objects edge in a digital image for visual interpretation. In order to amplify the line's feature of objects in RS image according to requirement of RS cartography, we deal them with edge enhancement. In the processed image, we can see that the edge of the major buildings and roads in county seat becomes clearly distinguishable.

3. Updating of different RS image data

To reveal the latest landscape of Lijiang region, it is necessary to update the RS data after finishing geometric rectification. The TM RS data is acquired in the first ten days of Apr. 2000, the SPOT panchromatic image is of Mar. 1999, and the aviation photo was taken in 1996, so we have TM image as the basically referenced image and update the SPOT image and airphoto respectively. The technique is based on the following principle.

In the same geographical conditions, the homogeneous objects have the same spectral feature in the same wave band. So its spectral feature will vary in most cases if one kind of object is covered by another. Thus, it illuminates that, after subtracting the two images with the same wave band but the different time parameter, you will find the regions that have changed obviously (the difference is great) are just the regions which are necessary to be updated. Basing on this knowledge, we can update the SPOT image by the following method:

The SPOT panchromatic spectra (0.51-0.73μ m) is the visible spectra. To imitate SPOT panchromatic, we select TM band 2 (0.52-0.6μ m) and TM band 3 (0.63-0.69μ m) to combine. Let:

$$TM_{23}=(TM_2+TM_3)/2 \qquad (8)$$

We get a new image of TM_{23}, then, subtracted TM_{23} image from SPOT panchromatic image and get the difference image ST_1.

Obviously, the difference image ST_1 not only concentrates most changed information between the two different periods, but also filtered the same background parts. To reduce the strong relativity between components of brightness vector of each output image's pixel, we use K-L (Karhumen-Loeve) transformation to process ST1, SPOT and TM_{23}, and generate a group of new multi-spectra image Y, here,

$$Y= AX \qquad (9)$$

Where X is the vector of pixels in image space before transformation, Y is the pixels vector in principle components space, A is the transposed matrix whose vector is the eigenvalue vector of the covariance matrix in X space.

Multiply each vector of pixel by matrix A, we can get each vector of the new image's pixel. According the principle of K-L transformation, the 1^{st} component y_1 in the principle components of new image concentrates the main information of ST_1, SPOT panchromatic image, and TM_{23}, that is to say that the dominating difference have been hidden in image y_1. So we use image y_1 as the updating image of TM and SPOT.

Data updating of color infrared aviation image and TM.

Supposing the digital aviation image consists of green-band p_1, red –band p_2 and near infrared band, we select TM band 2 (0.52-0.6μ m), TM band 3(0.63-0.69μ m) and TM band 4(0.76-0.90μ m) to correspond to them. Subtract TM band 2, 3 and 4 from corresponding aviation images p_1, p_2, and p_3 respectively. We can get:

$$PT_{12} = P_1-TM_2 \qquad (10)$$

$$PT_{23} = P_2 -TM_3 \qquad (11)$$

$$PT_{34} = P_3 -TM_4 \qquad (12)$$

Here, PT_{12}, PT_{23} and PT_{34} are the difference images of corresponding band. Then, we implement the K-L transformation of these images and get a new serial multi-spectra images z_i, from which we choose the first component image z_1 as the updating image of the color infrared airphoto and TM image.

4. Fusing of Multiple RS data

The method of IHS transformation is utilized for fusing of multiple RS data based on many experiments. The principle of fusing method using IHS transformation is as following:

IHS is a color mode which H, L and S represent hue, lightness and saturation respectively. The process of transforming the color image from the red green blue space to the brightness saturation and saturation space is called IHS transformation. And the counterpart is called anti-transformation. According to the transforming method from J.D.Foley etl[2], suppose R.G.B are all 0~ 1 float data, h is 0~ 360 float data, L and S are 0~ 1 float data except the h(hue) would have no definition when saturation S=0.The formula of calculating the brightness value is:

L= (Lmax+ Lmin) /2 (13)

In formula 13, Lmax is the most value of red, green, and blue, Lmin is the least value of red, green, and blue. As a particular status, when Lmax= Lmin, which means r = g = b belongs to the status of gray, where S=0, h has no definition.

The formula of calculating the saturation value is:

If L= = 0.5, then S= (S max- S min)/ (Smax+ Smin0);

If L> 0.5, then S= (S max- S min)/ [(1- Smax)+(1- Smin)];

The formula of calculating the hue value is:

Supposing d = Hmax- Hmin,

If Hr= Hrmax, then h= [(Hg-Hb)/d] × 60, which means the hue is between yellow and fuchsin.

If Hg=Hg max, then h=[2+(Hb-Hr)/ d] × 60,which means the hue is between cyan and yellow.

If Hb=Hb max, then h=[4+(Hr-Hg)/d] × 60, at this time the hue will jumped to the neighborhood of blue band, in other words it has jumped around the cyan and fuchsin.

In above, is h<0, we should add 360 degree to it in order to get the positive value in the fourth quadrant.

According the above calculation we can transform RGB mode to HIS mode, and on the contrary, we can transform HIS mode to RGB mode.

On the base of experiment, we applied the following methods to do image fusion for multi-source data of remote sensing:

Firstly perform the ISH transformation for a multi-spectral image built up from TM band 2, 4 and 7, afterwards, match the gray-level histograms of the two images: one is the renovated image named image y_1, the another is the I ponderance image comes from IHS transformation. During the matching, take the histogram of I ponderance image as reference, using a transformation function to change the distributing shape of the histogram of image y_1, then get an image Y_1 whose histogram is as alike as that of the reference. After histogram matching, image Y_1 can directly take place of the I ponderance image to make IHS anti-transformation with H, S ponderance image, then get the fused image.

The second step, make an ISH transform once more for the fused image. Let the gray-level histograms of two images are matched, one is the renovated image named image z_1, another is the I ponderance image comes from the IHS transformation. Then an image Z_1 whose histogram looks like that of the I ponderance image is gained. After histogram matching, image Z_1 can directly take place of the I ponderance image to make IHS anti-transform with H, S ponderance image, then get the last fused image.

5 Experiment steps, results and conclusion

The flowchart of image fusing is presented in Figure 1, original SPOT, AIRPHOTO and the merge image of TM band 2,3 and 4 are respectively displayed in figure 2, 3, and 4. The finally fused image is showed in figure 5.

It can be found that the images among Fig.2, 3, 4 and fig.5 are different in the same region by contrasting the original image and the fused image. In the fused image, various RS images information can supplement each other, so the fused image not only have abundant spectrum information, but also reserve high spatial resolution. It is easy to identify main streets and lager buildings in fused image, which proves that technique of RS image fusion is an important way to improve image's map-represent ability.

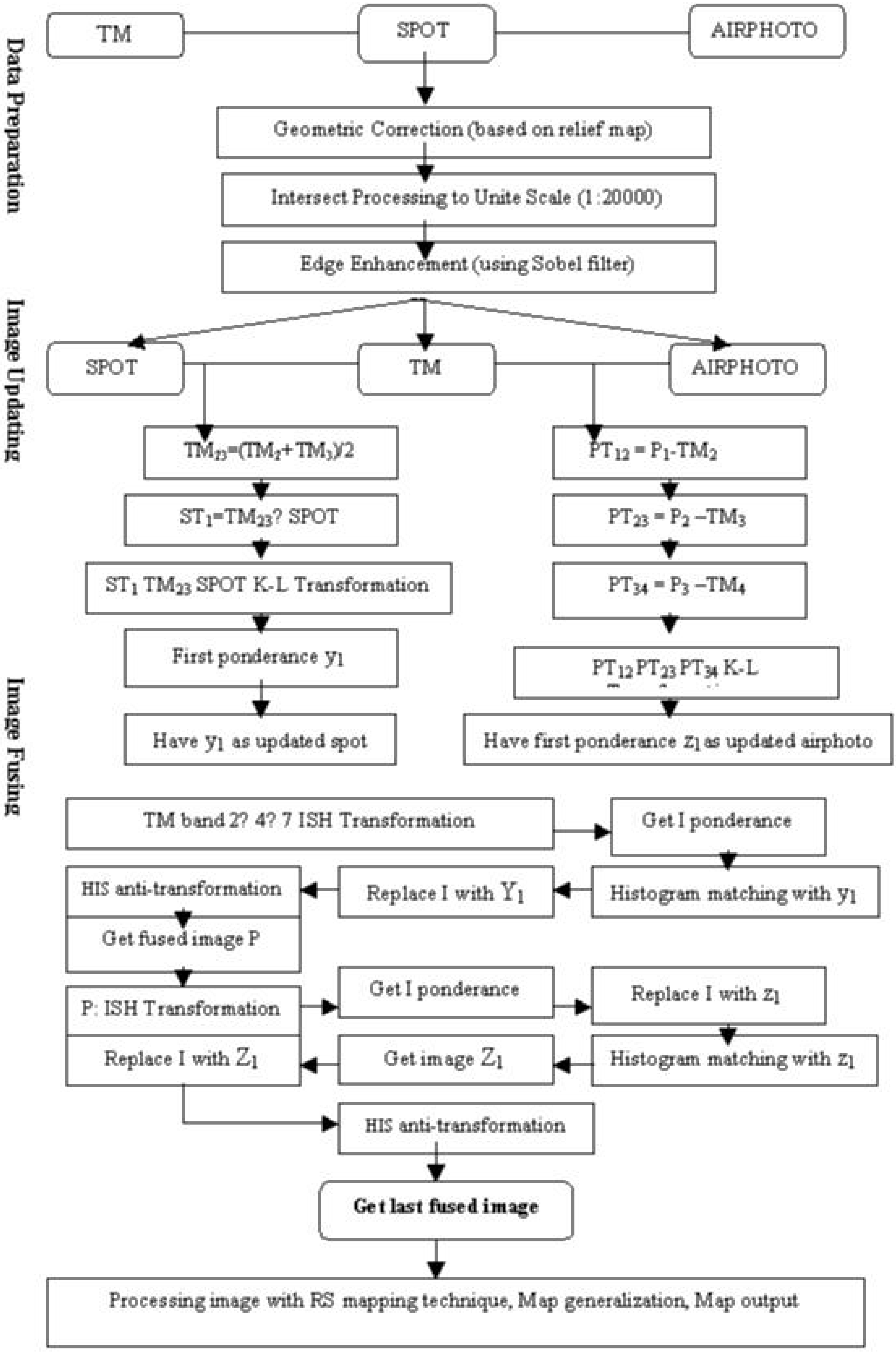

Fig. 1 The flowchart of image fusing

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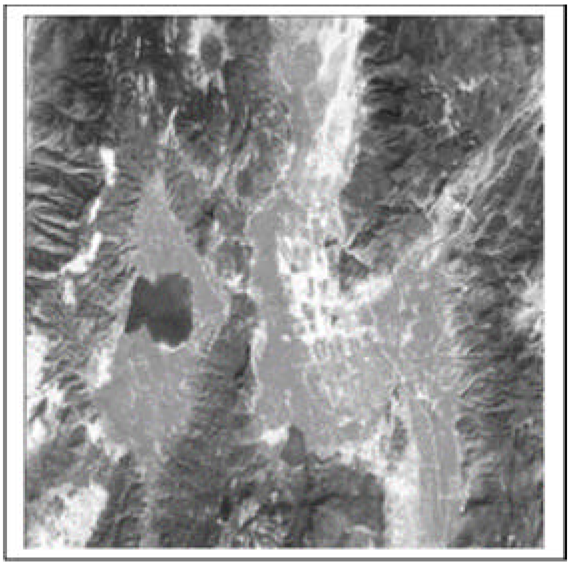

Fig.2 The original SPOT panchromatic image

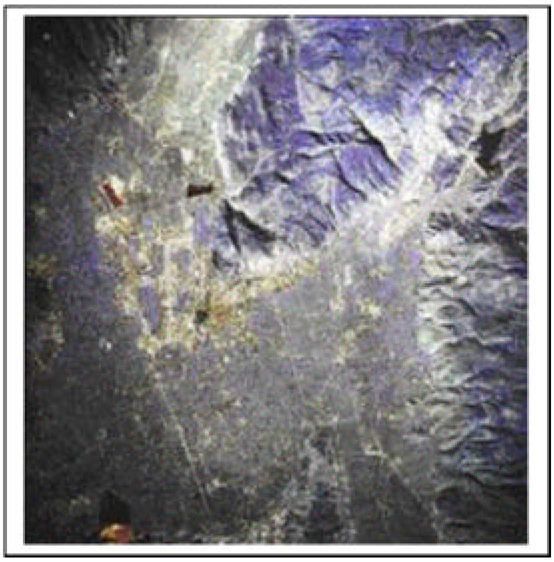

Fig. 3 The original airphoto

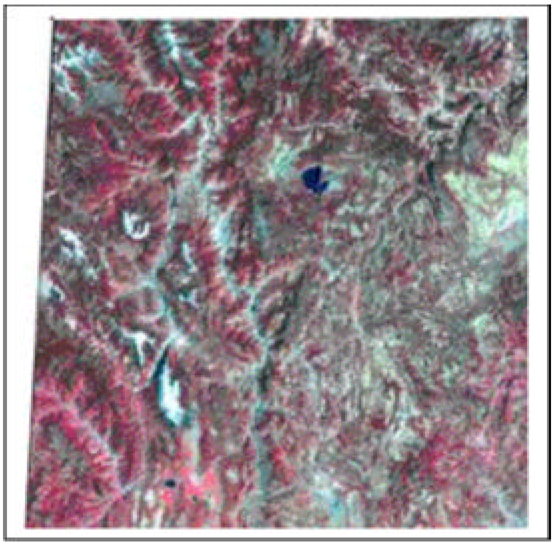

Fig. 4 The image merged from TM band 2,3,4

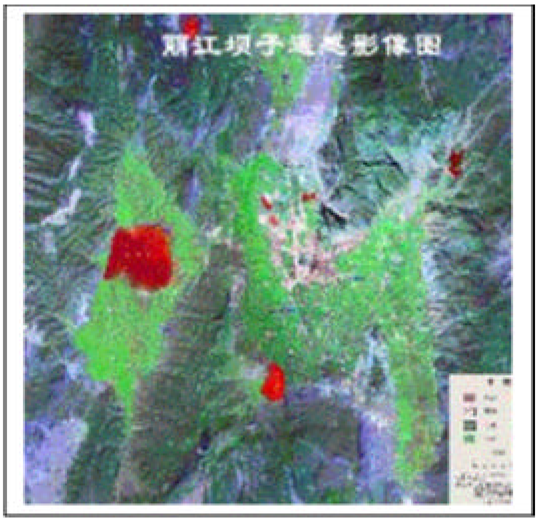

fig. 5 The final fused image