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An Improved Non-weighted Image Fusion Algorithm Based on High Pass Filter

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Abstract. Non-weighted image fusion based on high pass filter [1] can improve the spatial resolution greatly but cannot satisfactorily maintain the spectrum properties of the multi-spectrum image when using the Laplace enhancement operator as the high pass filter. As for this problem, this paper puts forward an improved algorithm and experimental results prove that it not only greatly increases the multi-spectrum image's spatial resolution but also satisfactorily maintains the spectrum properties of the multi-spectrum image.

Keywords: image fusion, high pass filter, non-weighted fusion, edge detection, laplace enhancement.

1. Introduction

These are some common image fusion algorithms based on pixels currently: image fusion based on high-pass filter, HIS transformation, wavelet transformation and ratio transformation and so on [2]. Of these algorithms, the image fusion based on high pass filter can maintain the spectrum properties of the multi-spectrum image to the greatest extend [3].

The image fusion based on high pass filter can be divided into two categories: non-weighted image fusion and weighted image fusion [4]. Between these two methods, the non-weighted image fusion based on high pass filter can further improve the spatial resolution compared with the weighted image fusion based on high pass filter but it cannot maintain the spectrum properties of multi-spectrum image well when using the Laplace enhancement operator. As for this problem, this paper puts forward an improved algorithm and analyses the experimental results of this algorithm and further improves this algorithm by solving the problems of random white spots and compression of high frequency components that the first improved algorithm brings about. The experimental results of the final improved algorithm demonstrate that it is better than the traditional non-weighted image fusion and the weighted image fusion based on high pass filter.

2. The Summary of the Traditional Non-Weighted Image Fusion Algorithm

This algorithm mainly contains two steps:

1)Filter the high resolution image by a high pass filter, and then suppose each pixel we get can be symbolized with $HP(i, j)$;

2) Add the high frequency components of the high resolution image we get above to each band of the low resolution multispectral image directly pixel by pixel. Suppose that the pixel of the Kth band of the multispectral image is expressed as $M_k(i, j)$, then $F_k(i, j)$ which represents the pixel value of the final image can be expressed as Formula (1):

$$F_k(i, j)=M_k(i, j)+HP(i, j)\,. \tag{1}$$

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3. The Introduction to the Data and the Experimental Platform

Experimental data: the multispectral image (Figure 1) and the panchromatic image of IKONOS (Figure 2) of certain areas in Wuhan, China.

Experimental platform: Visual C++

Fig. 1: Colour image of IKONOS

Fig. 2: Panchromatic image of IKONOS

4. The Improved Method of the Non-Weighted Image Fusion Algorithm Based On High Pass Filter

Figure 3 is the result when we fuse images using Laplace enhancement operator as the high pass filter according to the original non-weighted image fusion algorithm. Figure 4 is the result of the weighted image fusion based on high pass filter. Comparing Figure 3 and 4 with Figure 1, we find that the spatial resolution of Figure 3 and Figure 4 are greatly improved and that the spatial resolution of Figure 3 is higher than that of Figure 4, but its spectrum properties are changed a lot compared with Figure 1.

Fig. 3: The result of non-weighted fusion

Fig. 4: The result of weighted fusion

We made the following analysis of Figure 3: in this process, we directly add all the high frequency components of Figure 2(i.e., Figure 5) to each band of Figure 1, which causes the image to tend to grey, thus greatly changing the spectrum properties. However, if we only add a small amount of essential high frequency components to each band of Figure 1, it may ameliorate this problem. So we change the initial Laplace enhancement operator (Figure 7) to the new one (Figure 8) which in fact turns into an edge detection operator (Later, we call this first improved algorithm Improvement 1), and then conduct the non-weighted image fusion based on high pass filter and Figure 6 is the result. Comparing Figure 1, 3, 4, and 6, we find that Improvement 1 maintains the spectrum properties well while increasing the spatial resolution compared with the weighted image fusion. However, it generates many white spots in Figure 6 at the same time.

Fig. 5: Result of high pass filter

Fig. 6: Result of Improvement 1

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix} \qquad \begin{pmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{pmatrix}$$

Fig. 7: Laplace enhancement operator Fig. 8: Improved operator

We make the following analysis of the white spots of Figure 6: the first step of Improvement 1 is to filter the high resolution image by a high pass filter, but both the image details and the noise lie in the high frequency components [5, 6]; when we enhance the image details, we enhance the noise as well, thus generating the white spots.

So we try to further make some improvements: first, we filter the initial high resolution panchromatic image by using the high pass filter shown in Figure 8; then we detect edges in the initial high resolution panchromatic image(Figure 2); finally, we fuse these three images with the Formula (2)(Later, we call this improved algorithm Improvement 2) .And in this way we may eliminate the white spots.

$$F_k(i,j) = M_k(i,j) + C_2 \cdot \left[HP(i,j) - C_1 \cdot Edge(i,j) \right] \tag{2}$$

$F_k(i,j)$ represents the pixel value of the final fusion image, $M_k(i,j)$ represents the pixel value of the initial multispectral image, $HP(i,j)$ represents the pixel value of the panchromatic image filtered by the high pass filter shown in Figure 8, $Edge(i,j)$ represents the pixel value of the panchromatic image after edge detection and the coefficients C_1 and C_2 are constant which may be varied according to different images.

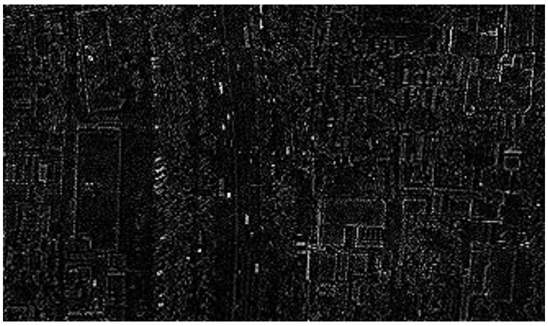

Fig. 9: Improved 1 high pass filter

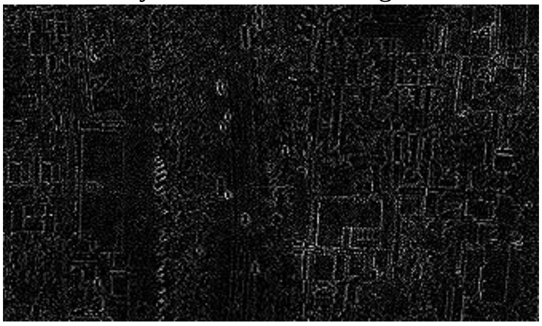

Fig. 10: Edge detection image

Before verifying our assumption, we use our new operator and Laplace edge detection operator to process Figure 2. Figure 9 is the result of the new operator (Figure 8) and Figure 10 is the image after edge detection. And we can see that Figure 9 and Figure 10 have much in common: both details and noise are intensified. So if we use the Formula (2) to fuse, we may offset the noise and eliminate the white spots.

Fig. 11: Fusion image of Improvement 2

Figure 11 is the image after processed by Improvement 2. Here, we set C_1 to 1 and set C_2 to 0.8. Comparing Figure 11 and Figure 4, we find that result using Improvement 2 has higher spatial resolution while maintaining the spectrum properties. Comparing Figure 11 with figure 6, we see that many white spots are eliminated and the outlines in figure 11 are clearer than that in Figure 6. As for why the outlines in Figure 11 are clearer than that in Figure 6, it can be explained as following: in Improvement 1, the sum of $M_k(i,j) + HP(i,j)$ is more than 255 ,thus the high frequency components of the final image are compressed, but in Improvement 2, the high frequency components are less compressed. Note that the compression in Improvement 1 cannot be solved by gray linear stretch or gray non-linear stretch.

To confirm the validity of our conclusions, we use mean grads (MG), variance and spatial frequency[7] (SF) to assess the resolution of the images[7,8,9,10], image entropy [11](IE) to assess image information and use distortion extent[7] (DE) and correlation coefficient[7, 12] (CC) to assess the spectral similarity between the fusion images and the original multi-spectrum image[7,8,9,10]. The image assessment results are listed in Table 1 and we can see that the results also support the conclusions above.

Table. 1: Assessment results on IKONOS data

	MG	variance	SF	IE	DE	CC
Figure 1	10.529	352.625	1.454	4.679		
Figure 3	46.644	394.180	8.994	7.437	26.269	0.770
Figure 4	28.220	395.685	4.096	7.481	11.284	0.938
Figure 8	45.673	518.941	10.145	6.727	18.574	0.855
Figure 11	52.503	492.241	12.127	7.565	20.436	0.833

From the results of experiment, we get an improved non-weighted image fusion algorithm based on high pass filter when using the Laplace enhancement operator as the high pass filter:

1) Filter the high resolution image by the high pass filter shown in Figure 8;
2) Detect edges in the initial high resolution panchromatic image with Laplace edge detection operator;
3) Fuse these three images with Formula (3).

$$F_k(i,j) = M_k(i,j) + C_2 \cdot \left[HP(i,j) - C_1 \cdot Edge(i,j) \right] \quad (3)$$

The coefficients C_1 and C_2 vary as appropriate.

In order to make the improved algorithm more convincing, we use the multi-spectrum image (Figure 12) and panchromatic image (Figure 13) of Quickbird as the second set of data to fuse. Figure 14 is the result of original non-weighted image fusion; Figure 15 is the result of weighted image fusion; Figure 16 is the result of Improvement 1 and Figure 17 is the result of Improvement 2. And here the coefficient C_1 is set to 1 and C_2 is set to 0.8. The image assessment results are listed in Table 2 and we find that Improvement 2 gets fine results with these data too.

Table 2: Assessment results on Quickbird data

	MG	variance	SF	IE	DE	CC
Figure 12	22.085	1198.295	3.530	7.267		
Figure 14	64.126	1405.431	26.832	7.776	35.770	0.757
Figure 15	41.178	1466.702	13.606	7.630	16.235	0.926
Figure 16	69.156	1843.575	34.204	7.538	26.804	0.806
Figure 17	79.590	1907.681	44.829	7.781	29.106	0.794


Fig. 12: Multi-spectrum image


Fig. 13: Panchromatic image


Fig. 14: non-weighted fusion


Fig. 15: weighted fusion


Fig. 16: Improvement 1


Fig. 17: Improvement 2

5. Conclusion

The traditional non-weighted image fusion algorithm based on high pass filter is able to increase the resolution of the multispectral image greatly but cannot maintain the spectrum properties in a relatively satisfying way when using the Laplace enhancement operator as the high pass filter. By taking the improved method in this paper, we solve this problem well. How to find the coefficient C_1 and C_2 quickly may still need further research. But in fact, the coefficient C_1 makes little difference if it is approximately equal to 1. So if we just set C_1 to 1, we can also get the well improved fusion image when C_2 is set properly.

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