
Multi-focus Image Fusion Based on Region Segmentation

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Abstract

We proposed a new image fusion algorithm based on region segmentation. The algorithm divided the adjacent region from the image through the edge detection, then using wavelet transform with different high-frequency fusion method in each sub-region, to retain the edge information of the source image. The experimental results showed that the image fusion algorithm based on region segmentation can overcome the drawbacks of single segmentation rule and processing in specific part, and the effect is better than the traditional wavelet-based image fusion algorithm.

Keywords: image fusion, multi-focus, region segmentation

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1. Introduction

Image fusion is the process of combining relevant information in two or more images of a scene into a single highly informative image [1]. The fused image should have more complete information which is more useful for human or machine perception. It can strengthen the image useful information and increase the reliability of the image understanding, and get more accurate results.

Image fusion methods can be broadly classified into two groups: spatial domain fusion and transform domain fusion [2]. The fusion methods such as averaging, Brovey method, principal component analysis (PCA) and IH6S based methods fall under spatial domain approaches [3-6]. Another important spatial domain fusion method is the high pass filtering based technique [7]. The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image [8]. The discrete wavelet transform has become a very useful tool for fusion. Some other fusion methods are also there, such as Lapacian pyramid based, curvelet transform based etc [9-10]. These methods show a better performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion [11].

In this paper, we have proposed a new image fusion algorithm based on region segmentation. The algorithm divided the adjacent region from the image through the edge detection, then using wavelet transform with different high-frequency fusion method in each sub-region, to retain the edge information of the source image. The experimental results showed that the image fusion algorithm based on region segmentation can overcome the drawbacks of single segmentation rule and processing in specific part [12], and the effect is better than the traditional wavelet-based image fusion algorithm.

The rest of this paper is organized as follow. The detailed description and the implementation steps of our proposed algorithm will be described in section 2. The evaluation method is presented in section 3, with results and conclusion in sections 4 and 5, respectively.

2. Improved Image Fusion Method

2.1. Image Segmentation based on Edge Detection

a. Image edge detection and connection

Image edge is one of the most basic characteristic of image, carrying most of information about an image [13]. Edge detection is a fundamental tool in image processing, machine vision and computer vision, particularly in the areas of feature detection and feature

extraction. There are many methods for edge detection, but most of them can be grouped into two categories, search-based and zero-crossing based.

Here we used Canny edge detector as edge detection operator [14], its detection principle is that look for local maximum value of the image gradient what is calculated by gaussian filter's reciprocal. Canny method use two thresholds to detect the strong edge and the weak edge, respectively and only when the weak edge and strong edge are linked together, the weak edge will be included in the result of output. Therefore this method is not susceptible to the interference of noise, thus it can detect the real edge.

b. Matlab implementation of image segmentation based on edge detection

In matlab, we use the edge function to do edge detection, and use thebwtraceboundary function and bwboundaries function to achieve boundary tracking, then through hough transform to achieve boundary connection [15].

Due to the focus of the source image A and B are different, make the image contained in the object's contour may appear different characteristics, some clear, some fuzzy. If we directly segment image A and B, separately, may lead to different the segmentation results of image A and B are different [16]. However the same target or object in different source images A and B, the data values of the low-frequency image's corresponding area are same or similar, and the high frequency image's data values are different [17]. Therefore, adopt the segmentation strategy for low frequency sub image. The operation steps are as follows:

(1) Wavelet transform is used to decompose image A and B into the low frequency subband image, respectively. Then do arithmetic mean operation for the low frequency image of the image A and B, we will get the fusion image, as shown in Figure 1.

(2) Execute image edge detection, Hough transform (Figure 2) and the edge connection to the fused image.

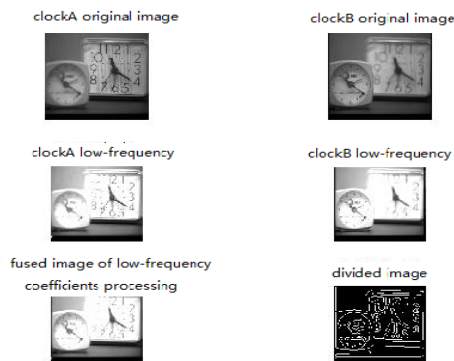


Figure 1. Image Segmentation Results

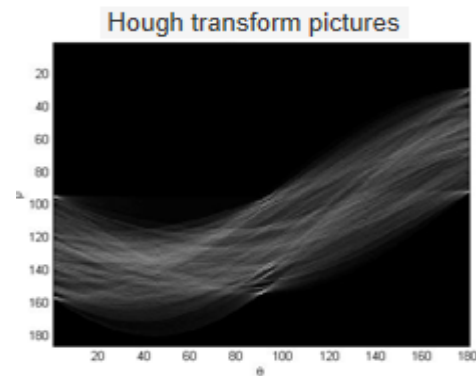


Figure 2. Hough Transform in the Parameter Space

2.2. Image Fusion Rules based on Regional Contrast

Due to low frequency subband reflects a general picture of an image, the difference is not big with the original image, so adopt a weighted average fusion rule for low frequency subband images. But in the high frequency part, because the fusion effect depends on the image details and clarity [18], consequently, after obtain segmentation image, we need to choose the suitable fusion rules for high frequency subband coefficients of each segment region to fuse, then get a high-frequency fusion operator image. According to the statistical characteristics of image, in this paper, the image fusion rules based on regional contrast is adopted to the fusion of high-frequency coefficient.

Regional contrast (definition) is the clarity extent of the image in the human eye. It sensitively reflects the tiny details contrast of the image [19], The regional contrast is defined as:

$$D = (I - I_B) / I_B \quad (1)$$

With I and I_B representing the luminance of the features and the background luminance, respectively. It is commonly used in cases where small features are present on a large uniform background, i.e. the average luminance is approximately equal to the background luminance. I is equal to the local low-frequency components of the image, and $I - I_B$ is equal to the local high-frequency components of the image. Get the regional contrast D of the original image A and B, respectively, by wavelet decomposition.

Set $L_{(2^j,1)}(x, y)$, $L_{(2^j,2)}(x, y)$, $L_{(2^j,3)}(x, y)$, as the low-frequency components, the vertical high-frequency components, the horizontal high-frequency component and diagonal high-frequency component what obtained by decomposing the image A in the 2^j scale space, respectively. The regional contrast $D_{i,A}$ that the high-frequency components of the image A in the region Z_i can be defined as:

$$D_{i,A} = \frac{1}{n_i} \left(\sum_{(x,y) \in Z_i} \left| \frac{H_{(2^j,1)}(x,y)}{L_{(2^j,1)}(x,y)} \right| + \sum_{(x,y) \in Z_i} \left| \frac{H_{(2^j,2)}(x,y)}{L_{(2^j,1)}(x,y)} \right| + \sum_{(x,y) \in Z_i} \left| \frac{H_{(2^j,3)}(x,y)}{L_{(2^j,1)}(x,y)} \right| \right) \quad (2)$$

In the formula 3, where i is the image block, where n_i denote the pixel number of the image block i . In the same way, the regional contrast $D_{i,B}$ of the image B can be calculated via the above formula.

The high frequency fusion image data value of the image A and B in the local area Z_i can be defined as follows:

$$d_{Z,(x,y \in Z_i)}(x, y) = k_A \cdot d_{A,(x,y \in Z_i)}(x, y) + k_B \cdot d_{B,(x,y \in Z_i)}(x, y) \quad (3)$$

Where the coefficients k_A and k_B are defined as follows:

$$k_A = \begin{cases} 0, & D_{i,A} < D_{i,B} \\ 1, & D_{i,A} \geq D_{i,B} \end{cases} \quad k_B = \begin{cases} 0, & D_{i,B} < D_{i,A} \\ 1, & D_{i,B} \geq D_{i,A} \end{cases} \quad (4)$$

Specific steps of fusion strategies are as follows:

(1) Wavelet decomposition is used to decompose image A and B into the low frequency subband and the each direction high frequency subband, respectively.

(2) Do arithmetic mean operation for the low frequency part of the image A and B, and divide the obtained image into several blocks by the method of edge detection.

(3) Within each block, calculate and compare the regional contrast of high frequency wavelet coefficients in image A and B, respectively. There by to determine the weighting coefficient of image A and B in each block.

(4) In the high frequency part of image, adopts regional contrast rules to conduct image fusion:

(5) Adopts the principle of arithmetic average in the low frequency part .

$$d_{Z,(x,y \in Z_i)}(x, y) = k_A \cdot d_{A,(x,y \in Z_i)}(x, y) + k_B \cdot d_{B,(x,y \in Z_i)}(x, y) \quad (5)$$

(6) Execute wavelet inverse transformation, then get the fused image from image A and image B.

3. The Standard of Evaluation

We set entropy, mutual information, average gradient as the evaluation standards [20], then conduct an comparative evaluation of the new method and traditional wavelet transform fusion algorithm.

(1) The image entropy can reflects average information of fused image and evaluates the stability of image, the image entropy is defined as:

$$H = -\sum_{i=0}^{L-1} p_i \log p_i \quad (6)$$

Where H is the image entropy, and L denotes the image's gray-level, and p_i denotes the ratio between the pixel numbers N_i that the gray value is i and the total number of pixels of the image. For a set of fusion experiment, when the image entropy of fused image is bigger and showing that the fusion performance is better [21].

(2) Mutual information. The mutual information of image A, B, F are defined as follows:

$$MI(A, B, F) = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} \sum_{k=0}^{L-1} p_{abf}(i, j, k) \log \frac{p_{abf}(i, j, k)}{p_{ab}(i, j)p_f(k)} \quad (7)$$

Where the $p_{ab}(i, j)$ denotes the normalized joint histogram equilibrium of image A and B, and $p_{abf}(i, j, k)$ denote the normalized joint histogram equilibrium of image A, B and F. The value of the mutual information is bigger show that fusion effect is better [22].

(3) Average gradient can reflect the image clarity, the value of average gradient is bigger and the image is more clear [23]. Average gradient value \bar{G} can be calculated as follows:

$$\bar{G} = \frac{1}{(M-1) \times (N-1)} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} \sqrt{\frac{(F(i+1, j) - F(i, j))^2 + (F(i, j+1) - F(i, j))^2}{2}} \quad (8)$$

Where $F(i, j)$ denote the gray value of the fused image cross i rows and j columns, M and N are the number of rows and the number of columns in the image, respectively.

4. Experiment Results and Analysis

We conduct an experiment compare the proposed method with the traditional wavelet fusion algorithm based on region variance [24]. The results as follow:

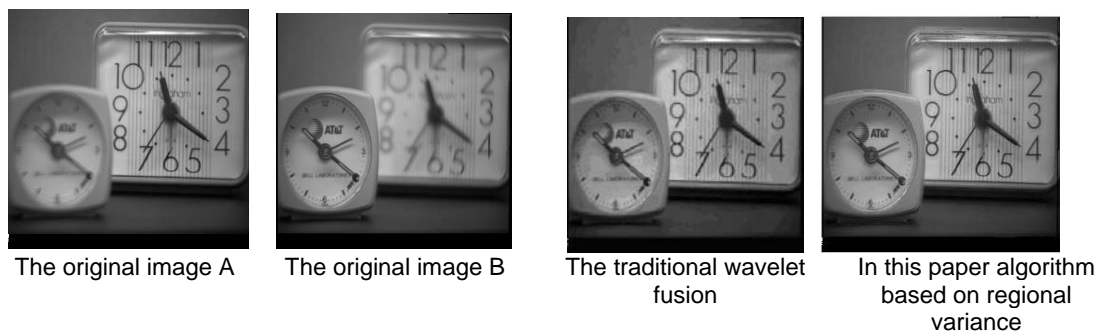


Figure 3. The Visual Results of Contrast Experiment

Adopt subjective evaluation method, from the visual effect aspect (Figure 3), the traditional wavelet fusion algorithm based on region variance and the method in this paper are able to extract the clear zone from the two blur source images respectively, and merge into an image. But the result of the latter method will be more clear. The experimental data (Figure 4) demonstrate that the improved algorithm's fusion effect is better than the traditional wavelet-based image fusion algorithm in the aspects of the average gradient, entropy and mutual information.

	The original image A	The original image B	The traditional wavelet fusion based on regional variance	In this paper algorithm
Average gradient	6.4606	5.1760	7.4126	7.6749
Entropy	7.4087	7.3245	7.3956	7.4463
Mutual information			0.2448	0.4410

Figure 4. Performance Comparison of Traditional Algorithm and the Proposed Method

5. Conclusion

This paper presents a new image fusion algorithm based on region segmentation, mainly improved by the traditional wavelet fusion algorithm based on region. The experimental results showed that the image fusion algorithm based on region segmentation can overcome the drawbacks of single segmentation rule and processing in specific part, and the effect is better than the traditional wavelet-based image fusion algorithm. Image fusion algorithm of this paper is suitable for the military and remote sensing, medical, transportation, industrial and other fields.

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