Advanced Materials Research *Online: 2013-08-30*
ISSN: 1662-8985, Vol. 748, pp 600-604
doi:10.4028/www.scientific.net/AMR.748.600

The Research on Multiscale Image Fusion Based on The Dualtree Complex Wavelet

Yi Luo[1] Guiling Yao[2] WeiFan Wang[3]

[1,2,3] Hubei University of Education. Wuhan, China 430205

[a] loyi2002@163.com, [b] yaoguiling666@163.com,[c] wangweifan8@163.com

Key words: Image fusion, Double tree after wavelet analysis, Fusion rules

Abstract. In order to effectively ease and solve fusion effect and the contradiction of the algorithm complexity, this paper puts forward a fusion rule on rapid extraction of multi-scale fusion coefficient, this fusion rules first used in the source image multi-scale decomposition of the scale fusion is the extraction of coefficient based on the neighborhood the fusion of window way, the low frequency of the improved neighborhood entropy to extract matching measure (that is, between the input image similarity degree), high frequency with the cross scale neighborhood gradient to extract matching measure, and gives the fusion coefficient formula. Because of the wavelet transform has moved degeneration, this paper puts forward the application of double tree after wavelet transform to do image multi-scale decomposition.

Ⅰ Introduction

Image fusion generally is geometric registration of imagery. It combines the information advantages and complementarities in each image to create a new image that meets some demand by means of a arithmetic. The crucial link of image fusion is the choice of Image decomposition scale and fusion rules. This paper analysis dualtree complex wavelet by using image analysis, extracts multi-scale fusion coefficient by using fusion method based on corresponding matching windows, extracts matching measure (i.e. similarity between input images) by using improved neighbor entropy for low frequency, extracts matching measure by using cross-scale neighbor gradient for high frequency, and provides the fusion coefficient equation. The low frequency one is the approximate son-band of image by using coefficient of neighbor measure based on neighbor entropy, it can embody gray scale and richness of information because entropy is an important measurement of image information richness; the high one is the minutia son-band of image by using neighbor measure coefficient, it can embody the mutation of gray scale because neighbor gradient is a measurement associated with gradient which embodies the marginalization.

Ⅱ Principles of arithmetic

A Dualtree complex wavelet transform

Multi-resolution analysis on orthogonal transform proposed by Mallat takes image samples in every hierarchy analysis, so this transform has translation alterability. Dualtree Complex Wavelet Transform(DT-CWT) proposed by Kingsbury is a kind of wavelet transform which has approximate translation inalterability, better direction selectivity, finite data redundancy and higher computing efficiency. It can extract image characteristic in all directions. DT-CWT is completely different from conventional complex wavelet translation, which can create real part and imaginary part of wavelet coefficient by using two real filter trees independently.

In order to make sure that all the value series that the two trees output have the same interval (all the values come form the original input of the first layer), the filter in one tree must keep the gap of half value from the other corresponding to relative sampling speed. As far as linear phase filter is concerned, it is required that filter of one filter should be odd length, the other be even length. If the different layers of every tree employ odd filter, even filter in turn, symmetry will be realized in two trees. In order to realize the reverse transformation operating, In every tree each reverse transformation operating can be performed by using biorthogonal filter with complete reconfigurativity in traditional real wavelet tree. At the end of image reconfiguration, it is necessary to average the output of two trees in order to control the aliasing effect and to approximately ensure the translation invariance of whole system.

B Fusion rules

The choice of fusion rules decides the quality and speed of fusion. It is the core of image fusion and it has not been well resolved so far. Although conventional image fusion by using weighing multi- distinguishability can produce rather good fusion effect, the choice of its weighing coefficients is very complicated and its arithmetic is extremely complex. In order to ease and resolve the conflict between fusion effect and arithmetic, this paper puts forward a fusion rule on rapid extraction of multi-scale fusion coefficient, this fusion rules first used in the source image multi-scale decomposition of the scale fusion is the extraction of coefficient based on the neighborhood the fusion of window way, the low frequency of the improved neighborhood entropy to extract matching measure (that is, between the input image similarity degree), high frequency with the cross scale neighborhood gradient to extract matching measure, and gives the fusion coefficient formula.

1)The Extracting Low Frequency Fusion Coefficients

The signals obtained in multi-scale analysis and included in approximate son-band are the ones of the image. It is necessary to calculate the neighbor entropy ratio which is used as the reference to extract fusing coefficient when fusion is being done by using method based on neighbor window. The correspondent positional value of fusion son-band is decided by the value of disintegrate son-band of fusion coefficients and source image. The neighbor entropy in this method is improved neighbor entropy.

a)Improving neighbor entropy

Neighbor entropy in this paper is defined as:

$$E = -\sum_{i=0}^{L-1} P_i \log P_i \qquad (1)$$

$P_i=n_i/(M\times N)$ is the probability that Gray Level i appears in neighbor window; $M\times N$ is the size of neighbor window; n_i is the pixel of Gray Level i.

It is obvious that the vaguer the image, the less the entropy value; the clearer the image, the bigger the entropy value for the same size of window; when two images have the same entropy values, they are extremely resemble.

We know from the above that neighbor window entropy as measure coefficient of low frequency son-band is extremely efficient, but it is essential to do logarithm operation, multiplying and division to solve the neighbor entropy, which spends a deal of time calculating. Besides, the times of add operation depends on how many pixels there are in window when calculating the emerging frequency of gray level i, which includes a lot of redundant operation. If we use a more simplified method to replace the calculation of neighbor entropy, then we census directly the data with gray level in neighbor window, and needn't do complex algebraic operation so as to improve calculating efficiency.

$E(p)$ ={x:x is the summary of all gray levels emerging in neighbor window p} (2)

If window is 3×3, maximum of x is 9, i.e., there are 9 gray levels.

In the process of calculating, this method uses flag variable to mark whether the current gray level has been summed up. if not, it sums it up; if yes it goes ahead and do next judgment.

b)Extracting fusion coefficients

The defined neighbor window entropy is employed as matching measurement in arithmetic. This matching measurement indicates the similarity of correspondent position in image. For Image A and Image B, suppose that formwork of window size is N, then matching measurement is expressed as follow:

$$R_{AB}(m,n)=E_A(m,n)/E_B(m,n) \qquad (3)$$

Here, (m,n) is the coordinate of pixel in Approximation Subband, $E_A(m,n)$ is the entropy of Image A whose formwork size is N and center is (m,n).

If $R_{AB}(m,n)$ is close to 1, it shows that the regional image entropies of Image A and Image B are close, so that Image A and Image B are similar in corresponding windows, or there is a large difference between them. Therefore neighbor window entropy ratio defined in this paper can stand for the similarity of the approximate part of input image.

Now, on the basis of matching measurement, figuring out a fusion coefficient to extract information characteristics of several similar subbands, then use this coefficient to compare which image information is more obvious. Neighbor window entropy ratio is the information characteristic in image window, and calculates its proportionate relationships. The choice of fusion coefficients decides the combining results of many images. The method of choice as follow:

$$d(m,n)=\begin{cases}1 & R_{AB}(m,n)\geq 1/T \\ 0 & R_{AB}(m,n)<T \\ 1/2+1/2[(1-R_{AB}(m,n))/(1-1/T)] & 1<R_{AB}(m,n)<1/T \\ 1/2-1/2[(1-R_{AB}(m,n))/(1-1/T)] & T<R_{AB}(m,n)<1\end{cases} \tag{4}$$

Here, T is threshold whose range is [0,1].

Approximate part of the final fusion image is:

$$C(m,n)=d(m,n)A(m,n)+(1-d(m,n))B(m,n) \tag{5}$$

2)Extracting fusion coefficients of high frequency

Detail subbands obtained from multiscale analysis are high frequency signals of the image. It aims at the characteristics of high frequency subband and employs neighbor measurement coefficients of cross-scale neighbor gradient to weigh the contribution of high frequency of each image.

For Image I whose window size is $M\times N$, its equation of gradient is defined as:

$$g=\sqrt{\frac{1}{MN}\left\{\sum_{m=0}^{M-1}\sum_{n=1}^{N-1}[I(m,n)-I(m,n-1)]^2+\sum_{n=0}^{N-1}\sum_{m=1}^{M-1}[I(m,n)-I(m-1,n)]^2\right\}} \tag{6}$$

Here, $I(m,n)$ is the gray value of the pixel whose position is at (m,n).

What included in high frequency subband image is associated with margin, so neighbor gradient values can be employed as neighbor measurement coefficients of detail subband of all directions. In addition, the coefficients with distinguishing feature in neighborhood have directivity and have similar directivity in continuous scale. Whereas the neighbor transform coefficients of noise distribute randomly in all directions, they are short of consistency in transform of neighbor directions. In view of these characteristics, this paper extracts measurement by using cross-scale neighbor gradient as fusion coefficients, so that noise can be restrained effectively in fusion image. The specific method is: when solving the measurement coefficient $Q_{j,v}(m,n)$(of high frequency detail subband $D_{j,v}$ in the position of (m,n) pixel of j layer, v direction.

$$Q_{j,v}(m,n)=g_{j,v}(m,n)\times g_{j-1,v}(m,n)\times g_{j+1,v}(m,n) \tag{7}$$

For Image A and Image B, their relativity is expressed as $R_{AB}(m,n)=Q^A_{j,v}(m,n)/Q^B_{j,v}(m,n)$, then the equation of extracting fusion coefficient (it is the same as the equation of extracting approximate component):

$$d(m,n)=\begin{cases}1 & R^{AB}_{j,v}(m,n)\geq 1/T\\ 0 & R^{AB}_{j,v}(m,n)<T\\ 1/2+1/2\left[(1-R^{AB}_{j,v}(m,n))\Big/(1-1/T)\right] & 1<R^{AB}_{j,v}(m,n)<1/T\\ 1/2-1/2\left[(1-R^{AB}_{j,v}(m,n))\Big/(1-1/T)\right] & T<R^{AB}_{j,v}(m,n)<1\end{cases}\tag{8}$$

Here, T stands for threshold value, on the basis of many experiments, its value is 0.6.

C Procedure of arithmetic

The steps if fusion arithmetic of this paper:

Resolve input image by means of DT-CWT, set up respective multi-resolution image series

Calculate selecting factors by using equation (1) for similar part, similar component of image, then obtain the similar part of fusion image by using equation (2).

Calculate selecting factors by using equation (3) for high frequency part of image and detail component of image, then obtain high frequency part of fusion image by using equation (4).

Perform inverse transformation to get final fusion image by using approximate component and detail component of fusion image.

Ⅲ Experiment

Figure 1(a) and Figure 1 (b) are chosen as source image in fusion experiment in which both of them are divided into three layers. In addition, Both neighbor window and consistency checking window are 3×3 large, dualtree complex wavelet transform employs 6 direction. Figure 2 is the contrast between traditional fusion image based on disperse wavelet transform and the fusion image created by means of the method proposed by this paper.

Fusion image (a) Fusion image (b)

Figure 1 The two images that need fusing

Figure 2 Contrast the results of two kind of fusion

From the subjective perspective, the image fusion quality employing the method of this paper is better than that employing traditional method based on disperse wavelet transform. Because there is no standard reference image in source image, fusion image is evaluated objectively by standard deviation, comentropy, average gradient, spatial frequency and average, etc..

(a) result of Image fusion method by using based on traditional disperse wavelet transform

(b) result of image fusion method proposed by this paper

Tab 1 The method comparing the quality of images

Evaluating method / Arithmetic	Comentropy	Standard eviation	Average
Traditional image fusion based on disperse wavelet transform	6.8889	0.1395	0.3089
Image fusion method proposed by this paper	7.2520	0.1770	0.3856

From the contrast results in Chart 1, it is clear that the comentropy based on traditional disperse wavelet transform is less than that based on the method proposed by this paper. Therefore the image of latter contains more information, for average or standard deviation the former is less than the latter. From the perspective of image statistical property, the bigger the standard deviation, the bigger the contrast of image, the more the information. Summing up these three respects, the method proposed by this paper can obtain better image quality.

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