IMAGE FUSION BASED ON WAVELET TRANSFORM

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Abstract: A new image fusion scheme based on wavelet transform has been proposed. The two input images are decomposed by applying Discrete Wavelet Transform upto the maximum level of decomposition possible. By decomposing the images, one approximation and three high frequency components of input image are obtained. The maximum coefficient rule is applied on the decomposed images to obtain the low and high frequency coefficients of the fused image. The fused image is obtained by applying Inverse Discrete Wavelet Transform. The performance measures for evaluating the fused image are entropy, correlation coefficient, mean and RMS value. The characteristics of the fused image are analyzed by the proposed method.

Keywords: Image Processing; Image Fusion; Wavelet Transform

I. INTRODUCTION

Image fusion is used to integrate the information of two or more source images in order to obtain more accurate, comprehensive and reliable description of the same scene [1]. As there is information redundancy and complementary among multiple images of the same scene obtained by different image sensors, it is particularly important to synthesize a new image by image fusion technology, which can provide more abundant information than original image [2]. Basically, there are many fusion algorithms available for fusion techniques. Some of them are

1. Intensity-Hue-Saturation Transform.
2. Principal Component Analysis Transform.
3. Laplacian Pyramid Method.

The above fusion algorithms are failure algorithms, because spatial and spectral characteristics of fused images are lost using these techniques. These algorithms are not suitable for two dimensional images. This paper applies the discrete wavelet transformation for the image fusion technique on multi focus and multi spectral images[4]. To the different frequency parts of image after decomposition, different fusion rules are adopted. The fusion of the low frequency high frequency images are obtained by using the absolute value maximum principle.

Rest of the paper is organized as follows: Section I deals with the basics of Image fusion. Section II presents with Wavelet Transform. Section III provides the experimental results. Section V ends with conclusion.

II. IMAGE FUSION

Image fusion is the process by which two or more images are combined into a single image retaining the important features from each of the original images. The fusion of images is often required for images acquired from different instrument modalities or capture techniques of the same scene or objects [6]. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics. Fusion techniques include the simplest method of pixel averaging to more complicated methods such as principal component analysis and wavelet transform fusion. Several approaches to image fusion can be distinguished, depending on whether the images are fused in the spatial domain or they are transformed into another domain, and their transforms fused. Basically, Fusion can be done by different types of Images such as

1. Multi Focus image fusion
2. Medical image fusion

A. Multi Focus Image Fusion

The two images to fuse are obtained by applying different side blurring to the same original image. The first image is obtained by blurring the left side
part of the original image while the second one is produced by blurring the right side part. The fused image will contain all the features of the original image.

B. Medical Image Fusion

In medical, CT and MRI image both are topographic scanning images and have different features. In CT image brightness is related to tissue density. So the brightness of bone is higher and some of soft tissue can’t be seen in CT images. In MRI image brightness is related to amount of hydrogen atom in tissues, thus brightness of soft tissue is higher, and bones can’t be seen. By using fusion technique, it can be possible to get both information in the single output image. The actual fusion process can take place at different levels of information representation; a generic categorization is to consider the different levels as

1. Pixel Level Fusion
2. Feature Level Fusion
3. Decision Level Fusion

C. Pixel Level Fusion

It is a low level fusion scheme and also a nonlinear method. In this fusion scheme intensity value of pixel of the source Images are used for merging the images. Most of the fusion techniques are used pixel level fusion scheme. Because, in this scheme provided output image closer to original image. It provides stereo viewing capability for stereo photogrammetry. It substitutes missing data. This fusion scheme does not introduce any inconsistencies. A typical pixel-level image fusion system can be divided into six subsystems: imaging, registration, pre-processing, fusion, post-processing and displaying.

III. WAVELET TRANSFORM

An alternative way to fusion using pyramid based multi resolution representations is fusion in the wavelet transform domain. The image fusion algorithm based on Wavelet Transform which faster developed was a multi-resolution analysis image fusion method in recent decade. Wavelet Transform has good time-frequency characteristics. Wavelets capture both time and frequency features in the data and often provides a richer picture than the classical Fourier analysis. Wavelet transform is a tool that cuts up data or functions or operators into different frequency components, and then studies each component with a resolution matched to its scale. Wavelet transform can be used as a multi resolution image fusion and medical image fusion at pixel level fusion scheme. Wavelets are successful in representing point discontinuities in one dimension, but less successful in two dimensions. By using wavelet transform fusion technique, the fused images are very close to output images.

The Daubechies wavelets are a family of orthogonal wavelets defining a discrete wavelet transform and characterized by a maximal number of vanishing moments for some given support. With each wavelet type of this class, there is a scaling function which generates an orthogonal multi resolution analysis [6]. In general, the Daubechies wavelets are chosen to have the highest number \( A \) of vanishing moments, for given support width \( N=2A \), and among the \( 2^{A-1} \) possible solutions. The one is chosen whose scaling filter has extremely phase. The wavelet transform is also easy to put into practice using the fast wavelet transform. Daubechies wavelets are widely used in solving a broad range of problems [9]. The wavelet transform decomposes the image into low-high, high-low, high-high, high-low, spatial frequency bands at different scales and the low-low at the coarsest scales. The LL band contains the average image information whereas the other bands contain directional information due to spatial orientation. Higher absolute values of wavelet coefficients in the higher bands correspond to salient features such as edges or lines.

A. Procedure for Image Fusion based on Wavelet Transform

1. Read two source images and resize both to same size.
2. Apply Mallet algorithm to decompose source images into low pass and high pass sub images.
3. At each level, we get four sub images. One low pass sub image, three high pass sub images (Horizontal, Vertical, Diagonal).
4. Apply max wavelet coefficients rule to find fused coefficients [8].
5. Apply Mallet reconstruction algorithm for construction from fused low pass and high pass coefficients. The fused image is obtained.
6. Calculate Entropy, Correlation Coefficient, Mean values and Root Mean Square (RMS).
7. Compare with other existing wavelets [7].
IV. EXPERIMENTAL RESULTS

The proposed method is implemented using Matlab 7.7. The two input images are decomposed by applying Discrete Wavelet Transform up to the maximum level of decomposition possible. The maximum coefficient rule is performed on the decomposed images which results in lower and higher frequencies of fused image. The fused image is obtained by applying Inverse Discrete Wavelet Transform. The simulation results are shown below.

Correlation Coefficient is used to measure strength of the linear relationship between pixels of an image. Its value lies between 0 to 1.

Correlation coefficient for two dimensional data

\[
gr = \frac{\sum \sum (A_{mn} - \bar{A})(B_{mn} - \bar{B})}{\sqrt{\sum \sum (A_{mn} - \bar{A})^2 \sum \sum (B_{mn} - \bar{B})^2}}
\]  

where, \(m, n\) are number of rows and columns of input image.

\[
\bar{A} = \text{mean value of } A.
\]

\[
\bar{B} = \text{mean value of } B.
\]

Entropy is a measure of disorder. Maximum entropy gives the smoothest and simplest image. It can be used to characterize the texture of an input image.

Entropy is defined as

\[
\text{Entropy} = -\sum (p_i \log_2(p_i)) \text{ Joule/kelvin} \tag{2}
\]

\(P\) is the histogram equalization of the input image.

Mean is an average expected value of an image. Mean is defined as

\[
\text{mean} = \frac{\sum i_1 + \ldots + i_n}{n} \tag{3}
\]

\(i\) is the pixel value

\(n\) is the number of pixels

Root Mean Square (RMS) value is the average error value of an image. Generally RMS is defined as

\[
\text{RMS for an image} = \frac{n}{\sqrt{\text{length}(n)}} \tag{4}
\]

\(n\) is the input image

In the Figure 2 (a) some parts of image is lost and in Figure 2 (b) other some parts of image is lost and in final image Figure 2 (c) image fusion is done by using wavelet transform. TABLE I. tabulates the performance measures for fused images.
Table I
Evaluation of the Multi-Focus Image Fusion Results

<table>
<thead>
<tr>
<th>Input images types</th>
<th>Wavelet</th>
<th>Correlation Coefficient (J/K)</th>
<th>Entropy</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lena 1</td>
<td>-</td>
<td>0.8889</td>
<td>7.4726</td>
<td>0.3878</td>
<td>6.4239</td>
</tr>
<tr>
<td>Lena 2</td>
<td>-</td>
<td>0.8890</td>
<td>7.4731</td>
<td>0.3879</td>
<td>6.4267</td>
</tr>
<tr>
<td>Lena 1 &amp; Lena 2</td>
<td>Symlet2</td>
<td>0.8889</td>
<td>7.4898</td>
<td>0.3879</td>
<td>6.4286</td>
</tr>
<tr>
<td>Lena 1 &amp; Lena 2</td>
<td>Coiflets2</td>
<td>0.8900</td>
<td>7.4880</td>
<td>0.3880</td>
<td>6.4285</td>
</tr>
<tr>
<td>Lena 1 &amp; Lena 2</td>
<td>Biorthogonal 4.4</td>
<td>0.8900</td>
<td>7.4898</td>
<td>0.3879</td>
<td>6.4286</td>
</tr>
<tr>
<td>Lena 1 &amp; Lena 2</td>
<td>Daubechies2</td>
<td>0.8900</td>
<td>7.4911</td>
<td>0.3888</td>
<td>6.4421</td>
</tr>
</tbody>
</table>

We use multi-focus lab images after standard testing. Figure 3 (a) shows left-focus image, the large clock looks clear. Figure 3 (b) shows right-focus image, the small clock looks clear. Figure 3 (c) represents the fused resultant of the above two input images using wavelet transform.

Figure 4: Multi-focus Lab Images and their Image Fusion (a) Right-focus (b) Left-focus (c) Fused Image of DWT

Table III
Evaluation of the Multi-Focus Image Fusion Results

<table>
<thead>
<tr>
<th>Input images types</th>
<th>Wavelet</th>
<th>Correlation Coefficient (J/K)</th>
<th>Entropy</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blur 1</td>
<td>-</td>
<td>0.9441</td>
<td>7.0858</td>
<td>0.3828</td>
<td>9.1534</td>
</tr>
<tr>
<td>Blur 2</td>
<td>-</td>
<td>0.9528</td>
<td>7.0516</td>
<td>0.3741</td>
<td>9.1515</td>
</tr>
<tr>
<td>Blur 1 &amp; Blur 2</td>
<td>Symlet2</td>
<td>0.9570</td>
<td>7.1684</td>
<td>0.3839</td>
<td>9.2001</td>
</tr>
<tr>
<td>Blur 1 &amp; Blur 2</td>
<td>Coiflets2</td>
<td>0.9584</td>
<td>7.1692</td>
<td>0.3837</td>
<td>9.2310</td>
</tr>
<tr>
<td>Blur 1 &amp; Blur 2</td>
<td>Biorthogonal 4.4</td>
<td>0.9584</td>
<td>7.1692</td>
<td>0.3837</td>
<td>9.2310</td>
</tr>
<tr>
<td>Blur 1 &amp; Blur 2</td>
<td>Daubechies2</td>
<td>0.9741</td>
<td>7.1685</td>
<td>0.3840</td>
<td>9.2000</td>
</tr>
</tbody>
</table>

Table IV
Evaluation of the Medical Image Fusion Result

<table>
<thead>
<tr>
<th>Input images types</th>
<th>Wavelet</th>
<th>Correlation Coefficient (J/K)</th>
<th>Entropy</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT image</td>
<td>-</td>
<td>0.9724</td>
<td>3.6720</td>
<td>0.2013</td>
<td>5.0171</td>
</tr>
<tr>
<td>MRI image</td>
<td>-</td>
<td>0.9353</td>
<td>6.6772</td>
<td>0.3741</td>
<td>6.4671</td>
</tr>
<tr>
<td>CT &amp; MRI image</td>
<td>Symlet2</td>
<td>0.9280</td>
<td>6.4127</td>
<td>0.3867</td>
<td>7.5130</td>
</tr>
<tr>
<td>CT &amp; MRI image</td>
<td>Coiflets2</td>
<td>0.8560</td>
<td>6.5848</td>
<td>0.3753</td>
<td>7.0470</td>
</tr>
<tr>
<td>CT &amp; MRI image</td>
<td>Biorthogonal 4.4</td>
<td>0.8335</td>
<td>6.4807</td>
<td>0.3799</td>
<td>7.2512</td>
</tr>
<tr>
<td>CT &amp; MRI image</td>
<td>Daubechies2</td>
<td>0.9280</td>
<td>6.6655</td>
<td>0.3869</td>
<td>7.0157</td>
</tr>
</tbody>
</table>

Here CT and MRI images are fused. The fused image contains both information of CT and MRI.
images. Fused image’s Entropy, Correlation Coefficient, Mean and RMS values are tabulated in Table IV. Wavelet transform provides maximum entropy and correlation coefficient value for fused image. The various wavelet transforms such as Daubechies (Db2), Symlet (Sym2), Coiflets (Coif2) and Biorthogonal (Bior4.4) are analyzed. From the observed results, it is inferred that Daubechies (Db2) has better correlation coefficient, entropy, mean and RMS. The proposed method shows the minimum RMS value for Db2 when compared to other wavelets. These values are used to analyse the characteristics of the fused image.

V. CONCLUSION

This paper puts forward an image fusion algorithm based on wavelet transform. Image fusion can also be improved by Curvelet Transform [5]. This transform operates, based on parabolic scaling law. It represents lines, edges and curves in two dimensional effectively. The experimental results show that the proposed scheme can preserve all useful information from primitive images and the clarity of fused image is improved.

REFERENCES


