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Image Fusion Techniques

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Abstract:-There are various different methods to collect information in a specific area.Often sensors are used to collect information due to its less cost and size. Single sensor cannot providing all the required information because of their design and observational constraints. So instead of single sensor, multi-sensor gives complementary information about the region and data. Due to multi-sensors different information of the same scene are provided and each image has been captured with different views. Here paper provides a method for evaluating the performance of image fusion algorithms. We define a set of measures of effectiveness for comparative performance analysis and then use on proposed algorithms that has been applied onimages.

Keywords—*Image fusion, Pixel base laplacian and wavelet fusion*

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I. Introduction

Image fusion is a process which includes combination of two or more images to form a new image by using a certain algorithm[4]. The overall fusion process consists of different fusion levels.The different fusion levels are: pixel-level fusion, feature-level fusion and decision-level fusion. In this paper, we have focused pixel-level fusion process, where a fused image is obtained from two input images.[4]

Multi-sensor images are combined by using advanced image processing techniques to obtain a fused image. Specifically, to increase the reliability of interpretation and to enhance the image more the integration of disparate and complementary data used. This leads to more accurate data and increased utility. The fused data provides for robust operational performance such as increased efficiency, improved reliability and improved classification.

There are different multi-resolution processing techniques which allows for a combination of edge information at different scales. Pixel base method most popular approach with wavelet transform fusion. Alsopyramid-based fusionmethods is described elsewhere. The rule for combining the detail information is an important issue. The most common rule for fusion is to take the detail coefficient with highest In pixel-level image fusion, some general requirements of pixel level fusion result are as:

(1) Fusion process should preserve all relevant information of the input imagery in the composite image (pattern conservation);

2) The fusion scheme should not introduce any artifacts or inconsistencies which would distract the human observer or subsequent processing stages;

(3) The fusion process should be shift and rotation invariant (i.e. the fusion result should not depend on the location or orientation of an object in the input imagery, which is crucial to pattern recognition or object detection).

Instead of quantitative evaluation of the quality of fused imagery; it is considered that most important for an objective comparison of the fusion algorithms' performances.(4)

II. Proposed Methodology

1) **Laplacian Pyramid Fusion**:

A set of band-pass copies of an image is referred to as the Laplacian pyramid due to the similarity to a Laplacian operator. In Laplacian pyramid each level is recursively constructed from its lower level by the following four basic steps: blurring (low-pass filtering); subsampling (reduce size); interpolation (expand); and differencing (to subtract two images pixel by pixel). The lowest level of the pyramid is constructed from the original image. The Laplacian pyramid was first introduced as a model for binocular fusion in human stereo vision, where the implementation used a Laplacian pyramid and a maximum selection rule at each point of the pyramid transform. (4)

Proposed Algorithm:

Step 1: Read two source images A and B of same size

Step 2: Reduce source images A and B

Step 3: Expand reduced images

Step 4: Calculate pyramid coefficients of actual level for both images

Step 5: Chose maximum coefficients

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Step 6: Apply consistency

Step 7: Apply final level analysis and reconstruct fused image.

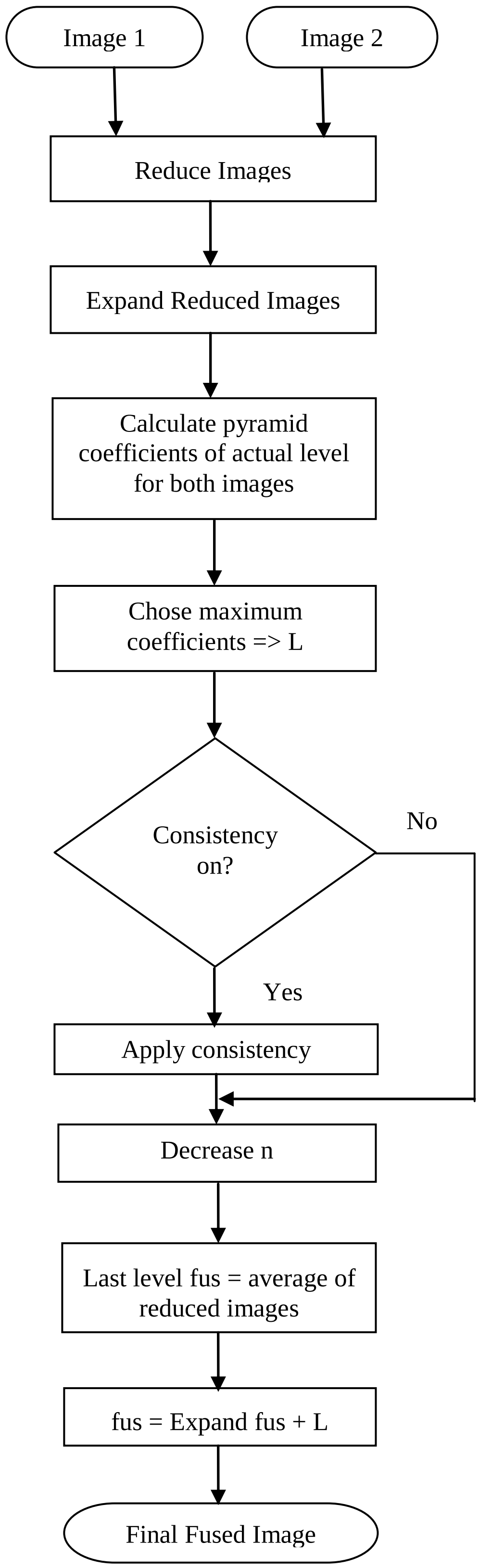

Figure 1.Work Flow of Proposed System 1

2. Wavelet Transform Based Image Fusion Algorithm

Image after wavelet decomposition can get a low-frequency and three of the high coefficients. The low-frequency generally changes smoothly with different sensors obtaining images of low-frequency, usually comparing whether they are the same or not. But the high coefficients generally reflect the source images of mutations and consequently of image fusion. The key is the high frequency part, and fusion rules. Fusion operator selection is also very important. This method takes on a different frequency band of sub-image using a different fusion processing technology. Low-frequency coefficients adopt the larger value method to get a low-frequency coefficient matrix of fused images. The corresponding high-frequency coefficient is based on the regional feature energy image fusion method. Finally, get the low-frequency and high frequency components and combine with wavelet inverter then get the images fused. (25)

Basic steps of image wavelet multi-scale decomposition:

1） Decomposition: Dividing original images into four sub-images respectively for getting different levels of different frequency bands of wavelet coefficients,

2） Fusion: For wavelet coefficients of the different characteristics, using different fusion rules and fusion operators, separate fusion processes are employed.

3） Inverse change: After the fusion process, the coefficients of wavelet inverse change leads to the formation of image fusion. As shown in Figure 2.

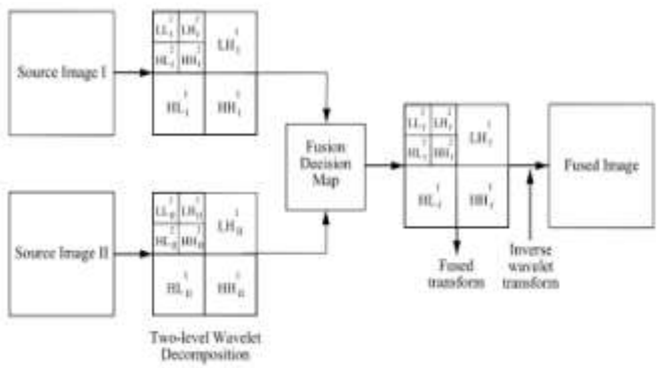

Figure2. Wavelet based Image Fusion

Algorithm:

Step 1: Read two source images A and B of same size
Step 2: Perform independent wavelet decomposition of the two images until level L to get approximation coefficients LL, LH, HL and HH.
Step 3: Apply pixel based algorithm for approximations which involves fusion based on taking the maximum valued pixels from approximations of source images.

$$LL^L_f = \text{maximum}\,(LL^L_I(i,j), LL^L_{II}(i,j))$$

Step 4: Apply binary decision fusion rule D_f for fusion approximation coefficients in two source images.

$$D_f(i,j) = 1, d_I(i,j) > d_{II}(i,j)$$
$$= 0, \text{otherwise}$$

Step 5: Then the final fused transform corresponding to approximations through maximum selection pixel rule is obtained.

Step 6: Apply inverse wavelet transform to reconstruct the resultant fused image and display the result.

III. Fused Image Quality Assessment Parameters:

Following parameters are used to assess quality of the fused image.

1 Entropy:

The image entropy is an important indicator for measuring the image information richness.

$$H = -\sum_{i=0}^{L-1} p_i \log p_i$$

where, H = Pixel entropy

L = Image total grayscale

Pi = i pixel rate to image total N that is Pi = Ni/N

2 Standard Deviation:

Standard deviation is reflects discrete case of the image gray intensity relative to the average. To some extent, the standard deviation can also be used to evaluate the image contrast size.

$$STD = \sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j)-\hat{\mu})^2 / MN}$$

where, μ is the mean value of gray-scale image fusion in the above formula[21].

3 Spatial Frequency:

Spatial Frequency Measurement (SFM) is used to measure the overall activity level of an image . The SFM can be used to represent the clarity of an image, defined as follows,

$$SF = \sqrt{RF^2 + CF^2}$$

where, RF and CF represented frequency in row and column spatial frequency of an image, respectively [21].

$$RF = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(F(m,n)-F(m,n-1))^2}$$

$$CF = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=2}^{N}(F(m,n)-F(m-1,n))^2}$$

4 Total Fusion Performance Parameter:

Total fusion performance $Q^{AB/F}$ is evaluated as aweighted sum of edge information preservation values for both input images Q^{AF} and Q^{BF} where the weights factors w^A and w^B represent perceptual importance of each input image pixel. The range is 0 = $Q^{AB/F}$= 1, where 0 means complete loss of input information has occurred and 1 indicates "ideal fusion" with no loss of input information.[21]

$$Q^{AB/F} = \frac{\sum_{\forall n,m} Q^{AF}_{n,m} w^A_{n,m} + Q^{AF}_{n,m} w^B_{n,m}}{\sum_{\forall n,m} w^A_{n,m} + w^B_{n,m}}$$

5 Fusion Loss:

Fusion loss LAB/F is a measure of the information lost during the fusion process.[21]

$$L^{AB/F} = \frac{\sum_{\forall n,m} r_{n,m}[(1-Q^{AF}_{n,m})w^A_{n,m} + (1-Q^{BF}_{n,m})w^B_{n,m}]}{\sum_{\forall n,m} w^A_{n,m} + w^B_{n,m}}$$

where,

$$r_{n,m} = \begin{cases} 1 \ , \ if \ g^F_{n,m} < g^A_{n,m} \ or \ g^F_{n,m} < g^B_{n,m} \\ 0 \ , \ otherwise \end{cases}$$

6 Fusion Artifact:

Fusion artifacts represent visual information introduced into the fused image by the fusion process that has no corresponding features in any of the inputs. Fusion artifacts are essentially false information that directly detracts from the usefulness of the fused image, and can have serious consequences in certain fusion applications. Total fusion artifacts for the fusion process A,B => F are evaluated as a perceptually weighted integration of the fusion noise estimates over the entire fused image [21].

$$N_{n,m} = \begin{cases} 2 - Q^{AF}_{n,m} - Q^{BF}_{n,m}, \ if \ g^F_{n,m} > (g^A_{n,m} \ \& \ g^F_{n,m}) \\ 0 \qquad\qquad\qquad , \ otherwise \end{cases}$$

$$N^{AB/F} = \frac{\sum_{\forall n,m} N_{n,m}(w^A_{n,m} + w^B_{n,m})}{\sum_{\forall n,m}(w^A_{n,m} + w^B_{n,m})}$$

7 Total Fusion Gain

The total fusion gain of a fusion process is the sum of the individual gains with respect to each input:[21]

$$Q^{AB/F}_{\Delta} = Q^{\Delta A/F} + Q^{\Delta B/F}$$

IV. Experimental Results:

The proposedalgorithm is tested over 50 database images. The performance parameter such as entropy, spatial frequency, standard deviation, total information transferred, total loss of information, fusion artifact, and fusion gain are calculated. The results of Six images are enlisted in tables.

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Source Image A : aeroplane_A.jpg


Source Image B : aeroplane_B.jpg


Image C: Wavelet based fusion


Image D: Laplace based fusion

Figure 3

Table 1: Performance characterisation Results

Parameters	**Source Image 1 3(A)**	**Source Image 2 3(B)**	**Wavelet Fused Image 3(C)**	**Pyramid Fused Image 3(D)**
Entropy	4.0177	3.9301	4.0169	4.1927
Standard Deviation	0.1884	0.1785	0.1932	0.1817
Spatial Frequency Criteria	0.0512	0.0439	0.0663	0.0516
Total Information Transferred			0.235	0.2089
Total Loss of Information			0.132	0.1821
Fusion Artifacts			1.2657	1.2178
Total Fusion Gain			0.1486	0.1269


Source Image A : house_B.jpg


Source Image B : house_B.jpg

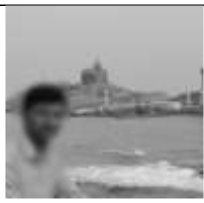

Image C: Wavelet based fusion


Image D: Laplace based fusion

Figure 4

Table 2:Performance characterisation Results

Parameters	**Source Image 1 4(A)**	**Source Image 2 4(B)**	**Wavelet Fused Image 4(C)**	**Pyramid Fused Image 4(D)**
Entropy	4.2133	4.1348	4.2641	4.149
Standard Deviation	0.1424	0.1665	0.1815	0.1681
Spatial Frequency Criteria	0.0681	0.0524	0.0482	0.0645
Total Information Transferred			0.5486	0.5434
Total Loss of Information			0.2125	0.3304
Fusion Artifacts			0.4144	0.1915
Total Fusion Gain			0.3116	0.2643


urce Image A : rakesh_A.jpg


Source Image B : rakesh_B.jpg


Image C: Wavelet based fusion


Image D: Laplace based fusion

Figure 5

Table :3Performance characterisation Results

Parameters	**Source Image 1 5(A)**	**Source Image 2 5(B)**	**Wavelet Fused Image 5(C)**	**Pyramid Fused Image 5(D)**
Entropy	6.4845	6.8289	6.8188	6.8281
Standard Deviation	0.1516	0.1558	0.1562	0.1529
Spatial Frequency Criteria	0.0241	0.0524	0.055	0.0504
Total Information Transferred			0.4599	0.452
Total Loss of Information			0.1185	0.1888
Fusion Artifacts			0.2852	0.158
Total Fusion Gain			0.1688	0.1465

Source Image A : colddrink_A.jpg

Source Image B : colddrink_B.jpg

Image C: Wavelet based Fusion

Image D: Laplace based Fusion

Figure 6

Table 4:Performance characterisation Results

Parameters	**Source Image 1 6(A)**	**Source Image 2 6(B)**	**Wavelet Fused Image 6(C)**	**Pyramid Fused Image 6(D)**
Entropy	4.5494	4.5414	4.5852	4.5528
Standard Deviation	0.2586	0.2405	0.2456	0.2585
Spatial Frequency Criteria	0.0449	0.0502	0.0612	0.0518
Total Information Transferred			0.4501	0.456
Total Loss of Information			0.1242	0.1952
Fusion Artifacts			0.2451	0.1412
Total Fusion Gain			0.1455	0.1458

Source Image A : tmeslogo_A.jpg

Source Image B : tmeslogo_B.jpg

Image C: Wavelet based fusion

Image D: Laplace based fusion

Figure 7

Table 5:Performance characterisation Results

Parameters	**Source Image 1 7(A)**	**Source Image 2 7(B)**	**Wavelet Fused Image 7(C)**	**Pyramid Fused Image 7(D)**
Entropy	6.5408	6.4501	5.8644	6.9449
Standard Deviation	0.5154	0.5144	0.5461	0.2951
Spatial Frequency Criteria	0.1524	0.1444	0.2046	0.151
Total Information Transferred			0.4451	0.549
Total Loss of Information			0.2545	0.5099
Fusion Artifacts			0.6408	0.6819
Total Fusion Gain			0.5045	0.2455

	
Source Image A : pepper_A.jpg	Source Image B : pepper_B.jpg
	
Image C: Wavelet based fusion	Image D: Laplace based fusion

Figure 8

Table 6:Performance characterisation Results

Parameters	Source Image 1 8(A)	Source Image 2 8(B)	Wavelet Fused Image 8(C)	Pyramid Fused Image 8(D)
Entropy	4.4424	4.4484	4.5121	4.4506
Standard Deviation	0.188	0.1941	0.2005	0.1895
Spatial Frequency Criteria	0.0406	0.0465	0.0546	0.0448
Total Information Transferred			0.6615	0.6655
Total Loss of Information			0.2041	0.5028
Fusion Artifacts			0.2624	0.0644
Total Fusion Gain			0.2895	0.2519

In order to test the performance of the proposed fusionalgorithm, The experiment is designed on two same siza images. Each image has different focuses and its size is 512×512 pixelsFusion process is carried on these images and calculates their performance parameters separately.All the performance parameters shows better result in wavelet transform than laplacian pyramid transform method except in real time images entropy of wavelet transform is less than laplacian pyramid method.

V. Conclusion

In this paper, we have presented method of image fusion like Laplacian pyramid transform and wavelet transform for multi-focus images fusion. The principle of Laplacian PyramidandWavelet transform fusion methods are describes in detail. Experimental studies are conducted by applying the proposed methods and calculates o fused quality assessment parameters. Experimental results shows that image fusion using wavelet transform is observed to be better than image fusion using laplacian pyramids. Output images of wavelet transforms are much more informative than the source images.

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