Comparative Study of Image Fusion Methods

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Abstract: Sensor networks are increasingly becoming an attractive method to collect information in a given area. However more than one sensors are required to providing the information, either because of their design or because of observational constraints. One possible solution to get all the required information about a particular scene or subject is data fusion. Multi-sensor data often presents complementary information about the region surveyed and data fusion provides an effective method to enable comparison, interpretation and analysis of such data. It is possible to have several images of the same scene providing different information about the same scene. This is because each image has been captured with a different sensor. In this paper we provide 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 them on the output of a number of fusion algorithms that have been applied to a set of real passive infrared (IR) and visible band imagery.

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

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I. INTRODUCTION

A fusion means, "The combination of two or more different images to form a new image by using a certain algorithm". Actual fusion process can take place at different levels of information representation. The different levels can be sorted in ascending order of abstraction: pixel, feature, and decision level. This paper focuses on the so-called pixel-level fusion process, where a composite image has to be built of several (typically two) input images.

Image fusion is a tool that combine multisource imagery by using specifically, it aims at the integration of disparate and complementary data in order to enhance the information apparent in the images, as well as to increase the reliability of the interpretation for accurate data and increased utility. Also fused data provides robust operational performance such as increased confidence, reduced ambiguity, improved reliability and improved classification.

Currently most of the pixel-based fusion techniques described in the literature. Many techniques are based on multi resolution processing which allows for a combination of edge information at different scales. A very popular approach is given by the wavelet transform. Use of pyramid-based fusion methods 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 energy (e.g. by simply choosing the highest absolute value in the DWT) from one of the bands (such as high-pass filtered bands). In pixel-level image fusion, some general requirements are imposed on the fusion result: (1) The 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). However, in this paper little consideration is given to Requirement (3) that only becomes crucial to some particular applications of image fusion (e.g. target recognition and tracking). Instead, quantitative evaluation of the quality of fused imagery is considered 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. Each level of the Laplacian pyramid 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). In the Laplacian pyramid, 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
Step 6: Apply consistency
Step7: Apply final level analysis and reconstruct fused image

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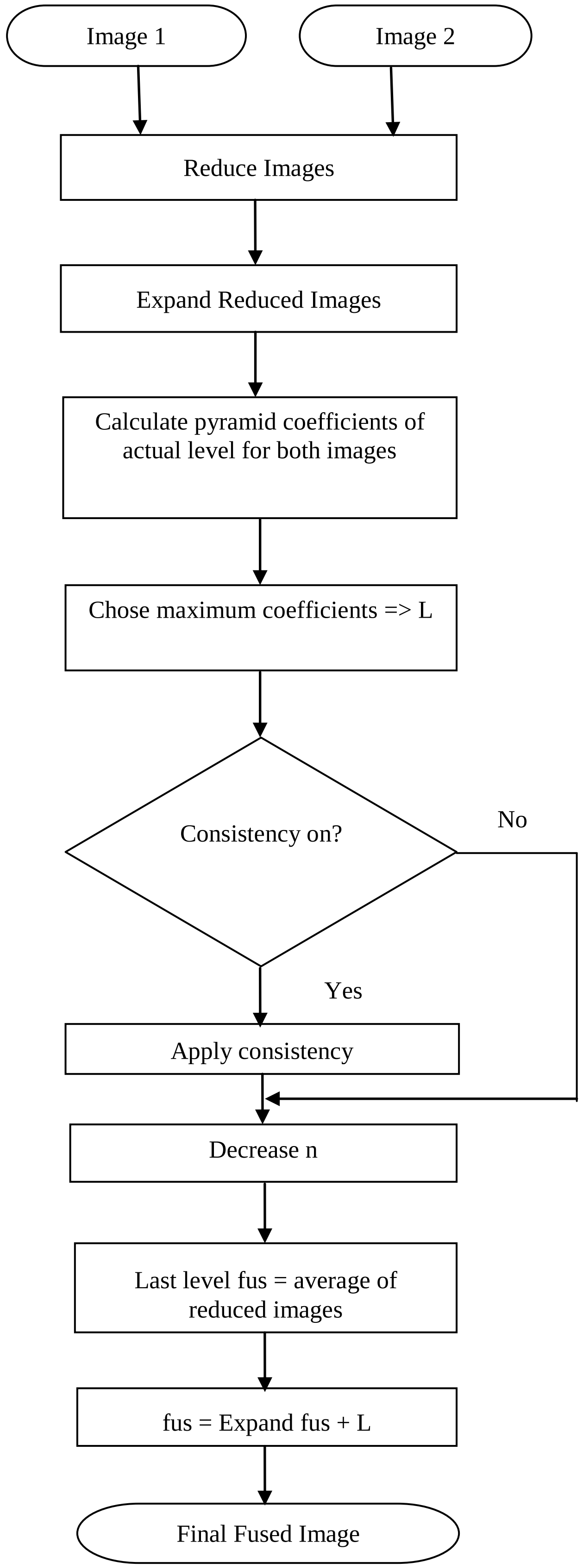

Figure 1 .Work Flow of Proposed System 1

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 sub-images respectively, and getting different levels of different frequency bands of wavelet coefficients,

2) Fusion: In view of the 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 Fig.

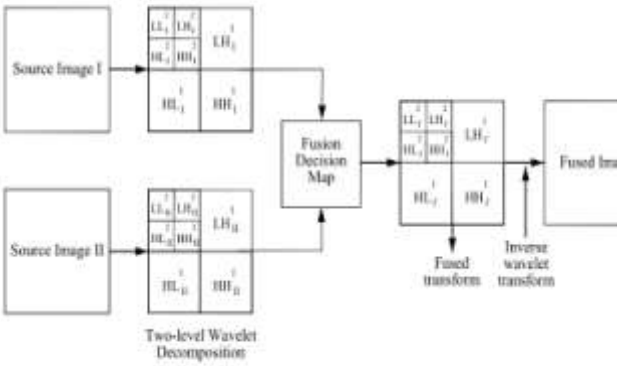

Figure 2. Wavelet based Image Fusion

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.

3 Spatial Frequency:

Spatial Frequency Measurement (SFM) is used to measure the overall activity level of an image [1]. 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.

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

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

4 Total Fusion Performance Parameter:

Total fusion performance $Q^{AB/F}$ is evaluated as a weighted 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.

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

5 Fusion Loss:

Fusion loss $^{LAB/F}$ is a measure of the information lost during the fusion process.

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

where,

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

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.

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

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

7 Total Fusion Gain

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

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

IV. Experimental Results:

The proposed algorithm is tested over 20 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.

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	7.5244	7.5217	7.5822	7.5303
Standard Deviation	0.1959	0.1903	0.206	0.1942
Spatial Frequency Criteria	0.1059	0.0445	0.1134	0.1018
Total Information Transferred			0.628	0.6225
Total Loss of Information			0.2225	0.3212
Fusion Artifacts			0.2986	0.1123
Total Fusion Gain			0.3404	0.2938

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Source Image A : boat_A.jpg

Source Image B : boat _B.jpg

Image C: Wavelet based fusion

Image D: Laplace based fusion

Figure 4

Source Image A : boat_A.jpg

Source Image B : boat _B.jpg

Image C: Wavelet based fusion

Image D: Laplace based fusion

Figure 5

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

Table :3 Performance characterisation Results

Parameters	**Source Image 1** 5(A)	**Source Image 2** 5(B)	**Wavelet Fused Image** 5(C)	**Pyramid Fused Image** 5(D)
Entropy	7.07789	7.06663	7.166766	7.070898
Standard Deviation	0.16169	0.16669	0.174892	0.162879
Spatial Frequency Criteria	0.48664	0.59001	0.073661	0.057695
Total Information Transferred			0.622925	0.603185
Total Loss of Information			0.217141	0.344011
Fusion Artifacts			0.319868	0.105608
Total Fusion Gain			0.351252	0.302416

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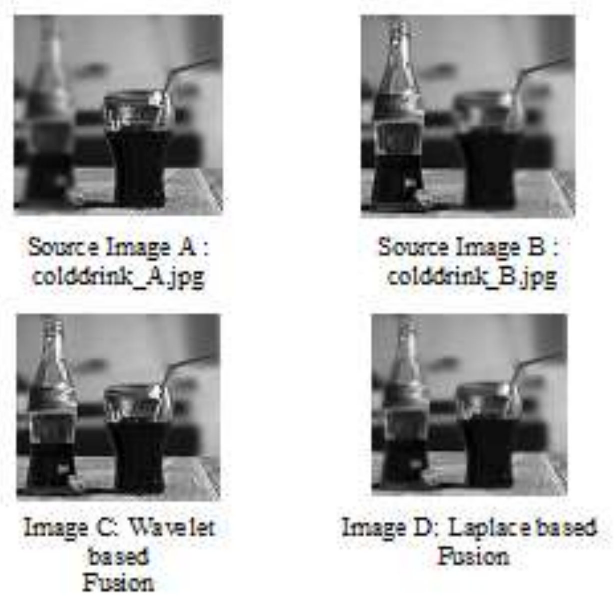

Figure 6

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

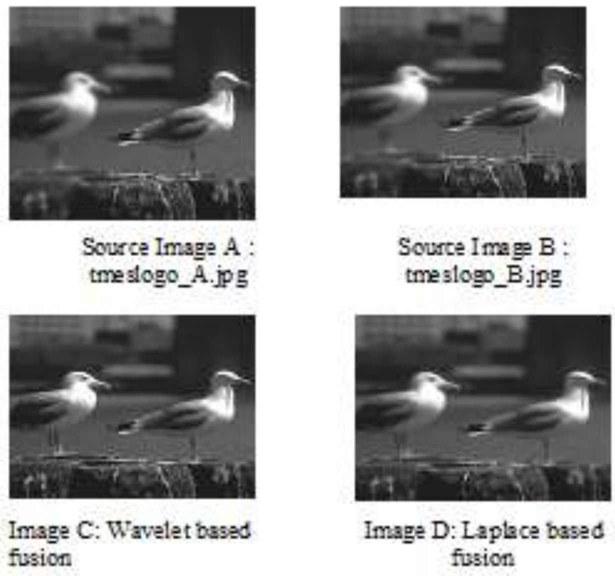

Figure 7

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	6.673087	6.65307	6.713984	6.684758
Standard Deviation	0.15588	0.15467	0.161725	0.154485
Spatial Frequency Criteria	0.38858	0.03682	0.049784	0.040089
Total Information Transferred			0.632888	0.626656
Total Loss of Information			0.197088	0.296347
Fusion Artifacts			0.340049	0.153993
Total Fusion Gain			0.306473	0.265832

In order to test the performance of the proposed fusion algorithm, The experiment is designed on two images . Each image has different focuses and its size is 512×512 pixels Fusion 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

According to assessment parameters of fused quality, wavelet transform is observed to be better than using laplacian pyramids image fusion .Fused images are much more informative than the source images. Wavelet transforms provide a framework in which an image is decomposed, with each level corresponding to a coarser resolution band. The wavelet-sharpened images have a very good spectral quality than laplacian pyramid method.

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