

Implementation of Image Fusion Technique

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Abstract — In image fusion, several images from different image sensors are fused in order to obtain a new image that contains more information and has more positive image description to the same scene. Single-sensor cannot provide 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 the use of multi-sensors, we can provide different information of the same scene and each image can be captured from different views. In this paper, two different image fusion techniques (laplacian pyramid image fusion and wavelet transform image fusion) are implemented and performance of the fused images are evaluated and compared. We define a set of measures of effectiveness for comparative performance analysis and then used on proposed algorithms that has been applied on different sets of images.

Keywords— Image fusion, Pixel based fusion, laplacian pyramid and wavelet fusion

I. INTRODUCTION

Image fusion is a process which consists of combination of two or more images to form a new image by using certain algorithms [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 source 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 based method is the most popular approach with wavelet transform fusion. Also pyramid-based fusion method is described elsewhere. The rule for combining the detailed information is an important issue. The most common rule for fusion is to take the detailed coefficients 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. 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.(4) The overall operation and proposed algorithm is as shown below.

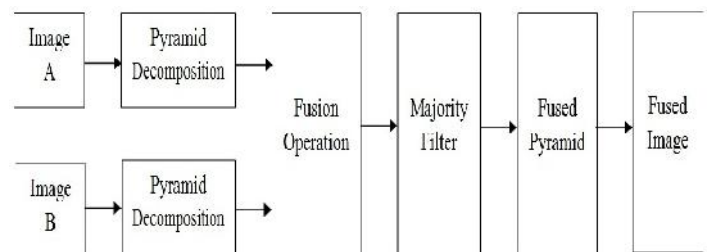


Figure 1: Laplacian Pyramid Fusion Method

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

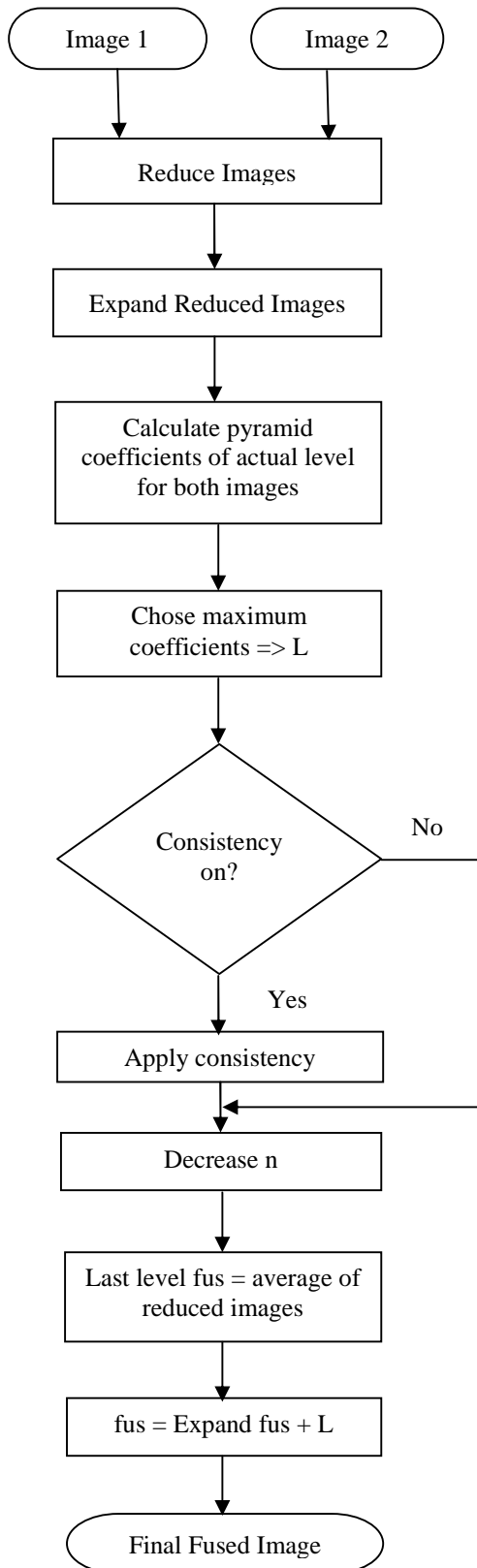


Figure 2: Work Flow of Proposed System 1

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.

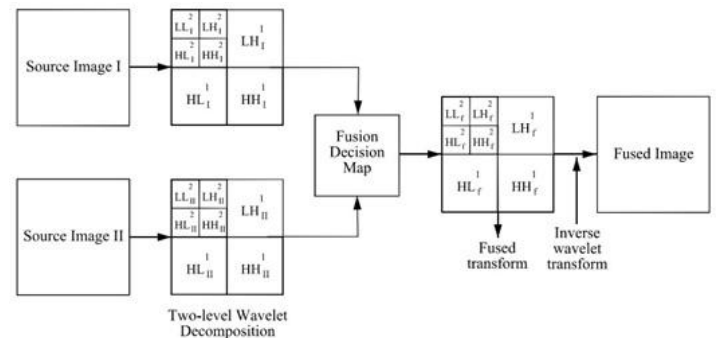


Figure 3: Wavelet based Image Fusion

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.

$$LL_f^L = \text{maximum}(LL_1^L(i,j), LL_2^L(i,j))$$
- Step 4: Apply binary decision fusion rule D_f for fusion approximation coefficients in two source images.

$$D_f(i,j) = 1, d_1(i,j) > d_2(i,j)$$

$$= 0, \text{ otherwise}$$
- 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. Standard Deviation (STD):

Standard deviation is used to reflect 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.

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

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

2. Entropy (H):

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

$$H = -\sum_{i=0}^{L-1} p_i \log p_i \quad (2)$$

where, H = Pixel entropy

L = Image total grayscale

P_i = i pixel rate to image total N that is $P_i = N_i/N$

3. Spatial Frequency (SF):

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,

$$SF = \sqrt{RF^2 + CF^2} \quad (3)$$

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

$$RF = \sqrt{\frac{1}{MN} \sum_{m=1}^M \sum_{n=2}^N (F(m, n) - F(m, n-1))^2} \quad (4)$$

$$CF = \sqrt{\frac{1}{MN} \sum_{m=1}^M \sum_{n=2}^N (F(m, n) - F(m-1, n))^2} \quad (5)$$

4. Total Fusion Performance Parameter ($Q^{AB/F}$):

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.

$$Q^{AB/F} = \frac{\sum_{\forall n,m} Q_{n,m}^{AF} w_{n,m}^A + Q_{n,m}^{BF} w_{n,m}^B}{\sum_{\forall n,m} w_{n,m}^A + w_{n,m}^B} \quad (6)$$

5. Fusion Artifact ($N^{AB/F}$):

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 $A, B \Rightarrow F$ are evaluated as a perceptually weighted integration of the fusion noise estimates over the entire fused image.

$$N_{n,m} = \begin{cases} 2 - Q_{n,m}^{AF} - Q_{n,m}^{BF}, & \text{if } g_{n,m}^F > (g_{n,m}^A \& g_{n,m}^B) \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

$$N^{AB/F} = \frac{\sum_{\forall n,m} N_{n,m} (w_{n,m}^A + w_{n,m}^B)}{\sum_{\forall n,m} (w_{n,m}^A + w_{n,m}^B)} \quad (8)$$

6. Total Fusion Gain ($Q^{AB/F}$):

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

$$Q_{\Delta}^{AB/F} = Q^{\Delta A/F} + Q^{\Delta B/F} \quad (9)$$

7. Fusion Loss ($L^{AB/F}$):

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

$$L^{AB/F} = \frac{\sum_{\forall n,m} r_{n,m} [(1 - Q_{n,m}^{AF}) w_{n,m}^A + (1 - Q_{n,m}^{BF}) w_{n,m}^B]}{\sum_{\forall n,m} w_{n,m}^A + w_{n,m}^B} \quad (10)$$

where,

$$r_{n,m} = \begin{cases} 1, & \text{if } g_{n,m}^F < g_{n,m}^A \text{ or } g_{n,m}^F < g_{n,m}^B \\ 0, & \text{otherwise} \end{cases} \quad (11)$$

8. Root Mean Square Error (RMSE):

The RMSE between the standard reference image R and fused image F can be defined as:

$$RMSE = \sqrt{\frac{\sum_{i=1}^M \sum_{j=1}^N (R(i, j) - F(i, j))^2}{M \times N}} \quad (12)$$

where, M = Number of rows in the image and

N = Number of columns in the image

9. Peak Signal to Noise Ratio (PSNR):

Peak signal to noise ratio can be defined as:

$$PSNR = 10 \log \frac{255 \times 255}{RMSE^2} \quad (13)$$

PSNR basically projects the ratio of the highest possible value of the data to the error obtained in the data.

IV. EXPERIMENTAL RESULTS

The proposed algorithm is tested over more than 50 database images. The performance parameters such as entropy, spatial frequency, standard deviation, total information transferred,

total loss of information, fusion artifact, fusion gain, root mean square error and peak signal to noise ratio are calculated. The results of some images are enlisted in tables.



Image Name	Reference Image	Source Image 1	Source Image 2	Pyramid Fused Image	Wavelet Fused Image
House and car					
Pepper					
Coca-Cola					
Birds					
Barbara					
AVCOE					

Figure 4: Comparison of the experimental results on different sets of images

Table 1: Performance Characterization Results for Image “House and car”

Parameters	Standard Deviation (STD)	Entropy (H)	Spatial Frequency (SF)	Fusion Performance ($Q^{AB/F}$)	Fusion Artifact ($N^{AB/F}$)	Fusion Gain ($Q^{AB/F}$)	Fusion Loss ($L^{AB/F}$)	Root Mean Square Error (RMSE)	Peak Signal to Noise Ratio (PSNR)
Laplacian Fused Image	0.1681	7.1790	0.0645	0.5734	0.1915	0.2673	0.3307	0.0305	63.3142
Wavelet Fused Image	0.1815	7.2671	0.0782	0.5786	0.4177	0.3116	0.2125	0.0145	66.5346

Table 2: Performance Characterization Results for Image “Pepper”

Parameters	STD	H	SF	$Q^{AB/F}$	$N^{AB/F}$	$Q^{AB/F}$	$L^{AB/F}$	RMSE	PSNR
Laplacian Fused Image	0.1893	7.4306	0.0448	0.6633	0.0674	0.2319	0.3028	0.0284	63.6208
Wavelet Fused Image	0.2005	7.5121	0.0546	0.6615	0.2627	0.2895	0.2071	0.0114	67.5637

Table 3: Performance Characterization Results for Image “Coca-Cola”

Parameters	STD	H	SF	$Q^{AB/F}$	$N^{AB/F}$	$Q^{AB/F}$	$L^{AB/F}$	RMSE	PSNR
Laplacian Fused Image	0.2383	7.5528	0.0518	0.7360	0.1412	0.1438	0.1932	0.0278	63.7163
Wavelet Fused Image	0.2456	7.5852	0.0612	0.7501	0.2451	0.1735	0.1272	0.0091	68.5412

Table 4: Performance Characterization Results for Image “Birds”

Parameters	STD	H	SF	$Q^{AB/F}$	$N^{AB/F}$	$Q^{AB/F}$	$L^{AB/F}$	RMSE	PSNR
Laplacian Fused Image	0.1544	6.6847	0.0401	0.6266	0.1539	0.2658	0.2963	0.0207	64.9994
Wavelet Fused Image	0.1617	6.7139	0.0497	0.6328	0.3401	0.3064	0.1971	0.0091	68.6109

Table 5: Performance Characterization Results for Image “Barbara”

Parameters	STD	H	SF	$Q^{AB/F}$	$N^{AB/F}$	$Q^{AB/F}$	$L^{AB/F}$	RMSE	PSNR
Laplacian Fused Image	0.1942	7.5309	0.1018	0.6225	0.1123	0.2938	0.3212	0.0295	63.4644
Wavelet Fused Image	0.2060	7.5832	0.1134	0.6281	0.2986	0.3404	0.2225	0.0119	67.3822

Table 6: Performance Characterization Results for Image “AVCOE”

Parameters	STD	H	SF	$Q^{AB/F}$	$N^{AB/F}$	$Q^{AB/F}$	$L^{AB/F}$	RMSE	PSNR
Laplacian Fused Image	0.1990	7.2413	0.0701	0.6520	0.0746	0.2713	0.3105	0.0241	64.3461
Wavelet Fused Image	0.2072	7.2962	0.0859	0.6493	0.2957	0.3155	0.2028	0.0080	69.1320

In order to test the performance of the proposed fusion algorithms, the experiments are performed on set of two source images. Each image has different focuses and size of each image is 512×512 pixels Fusion process is carried on these images and performance parameters are evaluated. All the performance parameters show better results in wavelet transform than laplacian pyramid transform method.

V. CONCLUSION

In this paper, we have presented two image fusion algorithms viz. laplacian pyramid and wavelet transform. Experimental studies were conducted by applying these two image fusion techniques. The comparisons of the fused images from the different techniques were made. Experimental results show that the fused images are much more informative than the input source images. According to fused quality assessment parameters, image fusion using wavelet transform is observed to be better than image fusion using laplacian pyramids. The wavelet-sharpened images have a very good spectral quality than laplacian pyramid method.

VI. REFERENCES

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