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# Image Fusion Based On Wavelet Transform and Gradient Pyramid Method

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## ABSTRACT

*Image fusion is the technique in which more than one images are fused to create new image so that the fuse image is more suitable for human perception. The objective in image fusion is to increase information and to extract the features that may not be normally visible in a single image that is relevant to a particular application. Fusion method algorithm is applied in input image in following ways: firstly the wavelet transform is used to construct the wavelet coefficients of fused image using multiple fusion operators and secondly the Gaussian pyramid method and gradient pyramid method is used and finally the DWT and gradient pyramid method is used. In this paper, a new approach is proposed (combine technique of DWT and gradient pyramid method) for evaluating the performance of image fusion algorithms based on PSNR (peak signal to noise ratio ), RMSE(root mean square error), MEAN and STANDARD DEVIATION. Based on the comparisons of the results obtained by the proposed method with the results achieved from the different fusion techniques demonstrate its higher performance for image fusion.*

***Keyword:***— *PSNR, RMSE, Mean, Standard Deviation, DWT, Guassian Pyramid, Gradient Pyramid*

## I. INTRODUCTION

Multi-focus image fusion is the process of combining the clear parts of two or more pictures, which are taken from one scene with the same digital camera, so as to get a single image with multi-objects distinct.[1]

The fusion of images is often required for images acquired from different instrument modalities or capture techniques of the same scene or objects. 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 Gradient pyramid method and wavelet transform fusion.[2]

Image fusion takes place at three different levels i.e. pixel, feature and decision. Image fusion methods can be broadly classified into two that is special domain fusion and transform domain fusion. Averaging, Principal Component Analysis (PCA), based methods are special domain methods. But special domain methods produce special distortion in the fused image. This problem can be solved by transform domain approach. The multi-resolution analysis has become very useful tool for analyzing images. The discrete wavelet transform has become a very useful tool for fusion [3].

There are two important questions in image fusion field: selection of wavelet name and decomposition level when wavelet transform is applied to multi-focus image fusion. And in the other hand, fusion rule is the kernel of image fusion and it directly influences the speed and quality of image fusion [1].

## II. Fusion Method

### *2.1 Discrete wavelet transforms:*

The two-dimensional fast wavelet algorithm is a pyramidal algorithm like the Gaussian pyramidal algorithm and is computationally efficient. The DWT coefficients are computed by using a series of low pass filter h[k], high pass filters g[k] and down samplers across both rows and columns. The results are the wavelet coefficient the next scale. The filter bank approach to calculate two dimensional dyadic DWT is shown in figure 1 and dyadic representation of the DWT is shown in figure 4. The wavelet coefficients are of smaller spatial resolution as they go from finer scale to coarser scale. The coefficients are called the approximation (A), horizontal detail (H), vertical detail (V) and diagonal detail (D) coefficient [3].

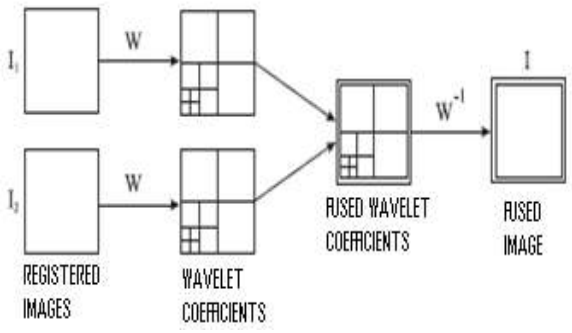


***Figure 1:*** *Wavelet multi-dimensional fusion*

### *2.2 Image pyramid:*

***2.2.1 Pyramid methods:*** An image pyramid can be described as collection of low- or band-pass copies of an original image in which both the band limit and sample density are reduced in regular steps. The basic strategy of image fusion based on pyramids is to use a feature selection rule to construct a fused pyramid representation from the pyramid representations of the original images. The composite image is obtained by taking the inverse pyramid transform. Several pyramid-based fusion schemes have been proposed in recent years, and are briefly described below: [3]

#### *(a) Gaussian pyramid:*

The Gaussian pyramid is a sequence of images in which each member of the sequence is a low pass filtered version of its predecessor [5].

#### *(b) Gradient pyramid:*

The gradient pyramid can be generated by applying gradient operators to each level of the Gaussian pyramid. This produces, horizontal,

vertical, and diagonal pyramid sets for each source in the Gaussian pyramid. An image fusion scheme that was based on a gradient pyramid and an activity measure within a small window rather than just a single point [6]

## III. Image Fusion Evaluation

So many evaluation criteria of image fusion exist, we mainly compares the effect of image fusion through the PSNR (peak signal to noise ratio), RMSE (root mean square error), mean, standard deviation and median to find out the best fusion result, and then the best fusion method (wavelet basis function, the decomposing level and the fusion operator) will be found.

### *3.1 Mean and Standard Deviation:*

The mean and standard deviation of image are calculated to get feature vector. Mean represents brightness and standard deviation represents contrast of image. If mean of image is high then it means that the image is bright and if mean is low then it means that the image is dark. The standard deviation is also calculated. The standard deviation reveals something about the contrast of image. If standard deviation is high then it shows the high contrast of image. If standard deviation is low then it will show the low contrast in image [6].

$$\mu_j = \frac{1}{N}\sum_{i-1}^{N} x_{ji} \qquad (1)$$

$$\sigma_j = \sqrt{\frac{1}{N}\sum_{i-1}^{N}(x_{ji} - \mu_j)^2} \qquad (2)$$

### *3.2 PSNR (Peak signal to noise ratio):*

The PSNR computes the peak signal-to-noise ratio, in decibels, between two images. This ratio is often used as a quality measurement between the original and a compressed image. Higher the PSNR better the quality of the compressed or reconstructed image [7].

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right) \qquad (3)$$

### *3.3 RMSE (Root mean square error):*

The RSME between the reference image and the fused image. The lower the value of RMSE the lower will be error [8]

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[X(i,j) - Xc\,(i,j)]^2 \qquad (4)$$

The RMSE is the square root of MSE.

RMSE = (MSE) $^{1/2}$

Where,

X (i, j) =original image

$X_c$ (i, j) =compressed image

M*N is size of input image

## IV. Experimental Results and Analysis

Experiments are performed on the 256x256 input images. Figure 2(a) is input image a is blur only half side of photo with adobe photoshop. Figure 2(b) is input image b blur only remaining half side of photo. Figure 2(c) is the output of DWT process of image fusion of operator mean –min is implemented using MATLAB [7.8.0.347(R2009a)] and Figure (d) is the output of gradient pyramid+ DWT. The image quality evaluation results of the fused images by different algorithms are given in Table 1 and 2 on the basis of judgment on RMSE and PSNR, the best method is the DWT+ Gradient pyramid (mean-min).

### *4.1 Experimental Images During Image Fusion Processes:*

(a) (b) (c) (d)

*Figure 2: Result of wavelet based image fusion and pyramid method (a) input image (b) input image (c) Fused by DWT (d) Fused by DWT + gradient pyramid*

**Table 1: Image quality evaluation results of the fused image (By DWT Method):**

| Method and Fusion Operator | Mean | Standard Deviation | Wavelet | Level | PSNR | RMSE |
|---|---|---|---|---|---|---|
| DWT (min-mean ) | 175.2 | 71.01 | HAAR | 2 | 35.84 | 4.118 |
| DWT(max-mean) | 177 | 69.81 | HAAR | 2 | 35.85 | 4.113 |
| DWT(mean-min) | 175.1 | 71.79 | HAAR | 2 | 37.22 | 3.511 |
| DWT(mean-max) | 175.1 | 160 | HAAR | 2 | 36.04 | 4.022 |
| DWT(max-max) | 177.2 | 162 | HAAR | 2 | 34.56 | 4.769 |

Results shown as in table 1 that the PSNR & MSE in case of mean-min operator of DWT method is better than the other one.

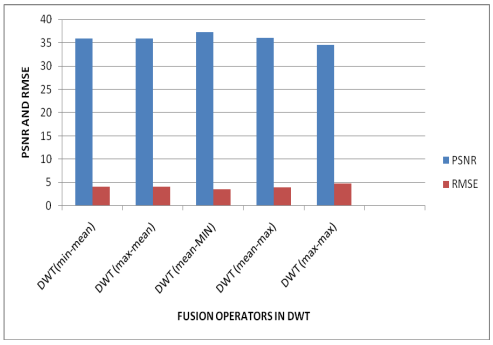


*Figure 3: Fusion Operators in DWT V/S PSNR & RMSE*

**Table 2: Image quality evaluation results of the fused image (By DWT and pyramid Method):**

| Method and Fusion Operator | Mean | Standard Deviation | Wavelet | Level | PSNR | RMSE |
|---|---|---|---|---|---|---|
| DWT+ Gaussian pyramid (mean-min) | 96.22 | 102.44 | HAAR | 2 | 38.24 | 3.121 |
| DWT+ Gradient pyramid (mean-min) | 85.22 | 59.5 | HAAR | 2 | 39.58 | 2.826 |

Results shown as in table 2 that PSNR & MSE in case DWT +gradient pyramid method is better than other one.

## V. CONCLUSION

In this paper an algorithm is proposed which is based on combine fusion algorithm of DWT +Gradient pyramid method to get more enhanced image. We compared the image fusion performance of different methods (gradient pyramid method and a regular DWT method) and our proposed algorithm based on four important quantitative measures − the root mean square error (RMSE), the peak signal to noise ratio (PSNR), the mean and the standard deviation. On the bases of four different measure our proposed algorithm i.e. ( DWT + gradient pyramid method ) performed the best.

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