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Comparative Analysis of PCA, DWT & Hybrid (PCA_DWT) Based Image Fusion Techniques

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Abstract— Image fusion can be defined as a combination of images from different sources aimed to obtain more informative or a more precise knowledge of the image. The main requirement of the fusion process is to identify the most significant feature in the input images and to transfer them without loss of detail in to the fused image. Depending on different fields of the applications, we have different objectives and goals for using image fusion.This paper discusses about the Formulation, Process Flow Diagrams and algorithms of PRINCIPAL COMPONENT ANALYSIS(PCA), DWT (Discrete Wavelet Transform and Hybrid (PCA_DWT) Transform based image fusion techniques. The results are also furnished in picture and table format. Paper concludes that DWT and Hybrid (PCA_DWT) is the best approach for image fusion.

***Index Terms*— image fusion: PCA, DWT and Hybrid (PCA_DWT) Transform Method**

1. INTRODUCTION

Image fusion is a useful technique for merging single sensor and multi-sensor images to enhance the information.
The objective of image fusion is to better visual understanding of certain phenomena and to introduce and enhance intelligence and system control functions. many advantage in multisensory data fusion such as improved system performance. Any piece of information makes sense only when it is able to convey the content across. The c1arity of information is important. This is achieved by applying a sequence of operations applied on the images that would make the good information in each of the image prominent. The fused image is constructed by combining magnified information from the input images

2. PRINCIPAL COMPONENT ANALYSIS

It is a mathematical tool from applied linear algebra .The PCA image fusion method simply uses the pixel values of all source images at each pixel location. adds a weight factor to each pixel value and takes an average of the weighted pixel values to produce the result for the fused image at the same pixel location. The origins of PCA lie in multivariate data analysis, it has a wide range of other applications, like important results from applied linear algebra and perhaps its most common use is as the first step in trying to analyses large data sets. In general terms, PCA uses a vector space transform to reduce the dimensionality of large data sets. Using mathematical projection, the original data set, which may have involved many variables, can often be interpreted in just a few variables (the principal components).

2.1. Formulation

Let us consider X be a D-Dimensional random vector and assume it to have zero mean. The orthonormal projection matrix V would be such that $Y = V^T X$ with the following constraints. The covariance of Y, i.e., COV(y) is a diagonal and inverse of V is equivalent to its transpose

$$V^{-1} = V^T$$

$$cov(y) = E\{Y.Y_T\} \quad (1)$$

$$cov(y) = E\{(XV_T)(V_TX)_T\} \quad (2)$$

$$cov(y) = E\{(XV_T)(VX_T)\} \quad (3)$$

$$cov(y) = V_T conv(X)V \quad (4)$$

Multiplying both sides of equation (4) by V, we get,

$$Vocv(Y) = VV_T$$

$$conv(X)V = conv(X)V \quad (5)$$

Substituting equation (4) into the equation (5) gives,

$$[\lambda_1 V_1, \lambda_2 V_2 \ldots\ldots\ldots, \lambda_d V_d]$$

$$= [conv(X)V_1, Cov(X)V_2, cov(X)V_d] \quad (6)$$

This could be rewritten asb

$$\lambda_i Vi = cov(X)\ Vi \quad (7)$$

Where, i =1, 2, ... , d and Vi is an eigenvector of cov(X)

2.2. PROCES FLOW DIAGRAM OF PCA

The process flow diagram of PCA algorithm is shown in below figure 1. The input images I1(x, y) and I2(x, y) are arranged in two column vectors and their empirical means are subtracted. The resulting vector has a dimension of n x 2, where n is length of the each image vector. Compute the eigenvector and eigenvalues for this resulting vector are computed and the eigenvectors corresponding to the larger eigenvalue obtained.

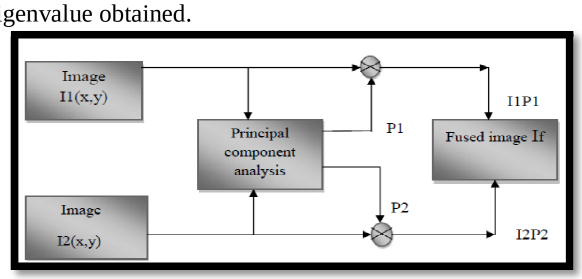

Figure.1. Image Fusion Process using PCA

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The normalized components PI and P2 are computed from the obtained eigenvector. The fused image is given by equation,

$$I_f(x,y) = P_1 I_1(x,y) + P_2 I_2(x,y) \quad (8)$$

2.3. PCA ALGORITHM

Let the source images be arranged in two-column vectors. The steps followed to project this data into 2-D subspaces are:

1. From the input images matrices arrange the data into column vectors. The resulting matrix Z is of dimension 2xn.
2. Then Compute the empirical mean along each column. The empirical mean vector Me has a dimension of 1 x 2.
3. Subtracting the empirical mean vector Me from each column of the data matrix S. The resulting matrix X is of dimension 2 x n.
4. Find the covariance matrix C of X i.e. C=XXT mean of expectation = cov(X)
5. Compute the eigenvectors V and eigenvalue D of C and sort them by decreasing eigenvalue. Both V and D are of dimension 2 x 2.
6. Finally consider the first column of V which corresponds to larger eigenvalue to compute PI an P2 as,[1]

$$P_1 = \frac{v(1)}{\sum v} \text{ and } P_2 = \frac{v(2)}{\sum v}$$

3. DISCRETE WAVELET TRANSFORM

The Discrete Wavelet Transform (DWT) also converts the image from the spatial domain to frequency domain. The image is divided by vertical and horizontal lines and represents the first-order of DWT, and the image can be separated with four parts those are LL1, LH1, HL1 and HH1. In additional, those four parts are represented four frequency areas in the image. For the low- frequency domain LL1 is sensitively with human eyes. In the frequency domains LH1, HL1 and HH1 have more detail Information more than frequency domain LL1.

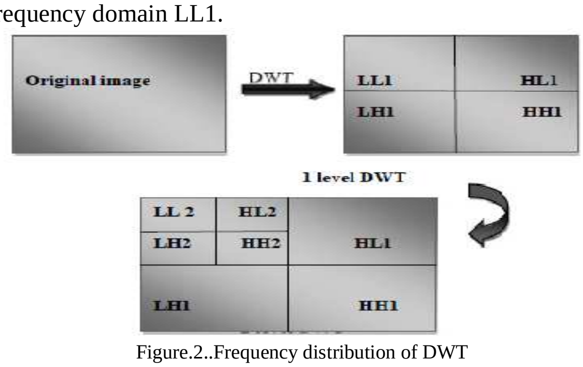

Figure.2..Frequency distribution of DWT

3.1. Process Flow Diagram of DWT

Wavelet transform is first performed on each source images to generate a fusion decision map based on a set of fusion rules. The fused wavelet coefficient map can be constructed from the wavelet coefficients of the source images according to the fusion decision map. Finally the fused image is obtained by performing the inverse wavelet transform

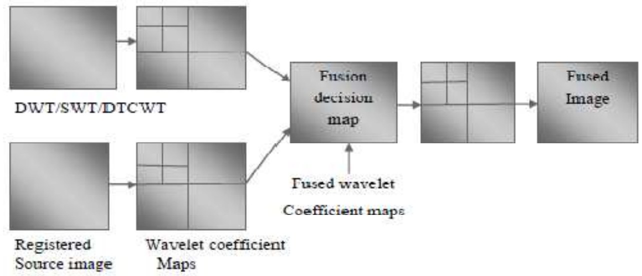

Figure.3.Processof image fusion using DWT

The fusion rules play a very important role during the fusion process.

1. Implement the DWT on both the input images to create lower decomposition wavelets.
2. By using different fusion rules fuse each decomposition levels.
3. Apply IDWT on fused decomposition levels, to reconstruct the original image that is fused image.

3.2. Algorithms

The algorithm of image fusion using DWT has following common steps applicable to proposed methods of fusion.

a) Accept the two input images.
b) Resize both the images to 256 x 256.
c) Convert to Gray scale image.
d) Convert to double precision format.
e) Take Discrete Wavelet Transform of both the images.
f) Let for first image OUT bands be HHa, HLa, LHa, LLa and for second image be HHb, HLb, LHb, LLb.

4. HYBRID METHOD(PCA &DWT)

The proposed method that combines the PCA method with wavelet transform provides outstanding outcomes compared to standard PCA or wavelet transform alone. Wavelet transforms are generally classified into three categories; continuous, discrete, and multiresolution based [4]. In discrete wavelet transform, while decomposition is applied, the estimation and information element can be different. 2D DWT transforms echocardiography image from spatial domain to frequency one. Input is separated to horizontal and vertical outlines and shows the DWT first order; then image is divided to 4 areas which are LL1, LH1, HL1, and HH1. When decomposition is performed, the L-L band provides the typical image info while other bands include directional information caused by spatial orientation. Higher complete wavelet coefficients value within the high bands related to important characteristics include lines or edges. As a result, in wavelet transform, the size of image is halved in spatial direction at every decomposition level of procedure, therefore ending to a multiresolution signal representation. The main phase for combination is the creation of combination pyramid.

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4.1. The Proposed Hybrid Fusion Methods

The figure.5. Shows the proposed hybrid fusion block diagram. It consists of two source input images, HPF, DWT, and PCA fusion blocks. In two input image first apply the HPF approaches then multiply both the images. Then apply the DWT method for both the input image. Then finaly apply the PCA approach for multiply and DWT methods. Output image will be fused image.

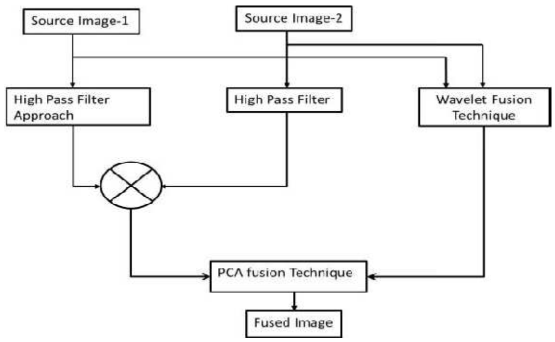

Fig.4. Proposed Hybrid Fusion

4.2 Algorithm for Hybrid Fusion

1. Input two multi-focus images
2. Rescale the images as per requirement.
3. Apply DWT technique on images.
4. Apply High Pass filter to images.
5. High-spatial contents extracted from the images using high-pass filter are concatenated.
6. Fused image obtained after applying wavelet technique & High spatial contents of the images after concatenation are fused together using PCA technique.
7. Finally the fused image is obtained

5. QUALITY MEASURES

a. Mean Square Error

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} - B_{ij})^2$$

b. Peak Signal to Noise Ratio

$$PSNR = 10 \times \log_{10}\left(\frac{peak^2}{MSE}\right)$$

c. Average Difference

$$AD = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\left|A_{ij} - B_{ij}\right|\right)$$

d. Structural Content

$$SC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2}{\sum_{i=1}^{m}\sum_{j=1}^{n}(B_{ij})^2}$$

e. Normalized Cross Correlation

$$NCC = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} * B_{ij})}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})^2}$$

f. Maximum Difference

$$MD = \max\left(\left|A_{ij} - B_{ij}\right|\right),\ i - 1,2,\ldots\ldots m;\ j - 1,2,\ldots\ldots n$$

g. Normalized Absolute Error

$$NAE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(\left|A_{ij} - B_{ij}\right|\right)}{\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij})}$$

6. RESULTS

Following images are results of fusion process with PCA, DWT and Hybrid(PCA_DWT) fusion technique.

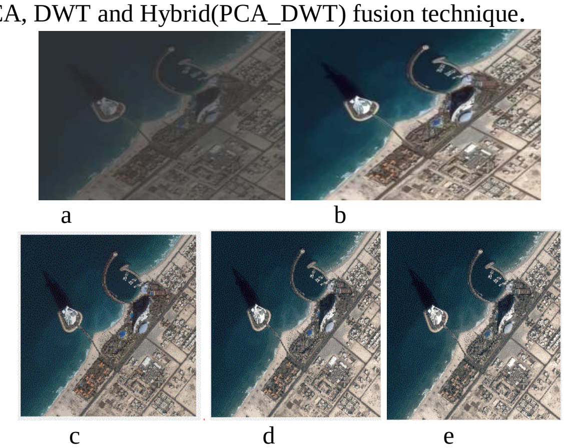

Figure 6.1 color output image; (a).First input imagelow resolution; (b).Second input image high resolution ; (c).Fused image using PCA; (d).Fused image using DWT; (e).Fused image using Hybrid(PCA_DWT)

Following Table demonstrates the various quality measures for different image fusion techniques of the above result figure 6.1.

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TABLE 1
Fusion Techniques & Their Quality Measures

QUALITY MEASUREMENTS	FUSION METHODS		
	PCA	DWT	Hybrid(PCA_DWT)Transform
PSNR	69.5045	75.9526	76.3094
Average Difference	.1108	.0466	.0490
Mean square error	.0073	.0017	.0015
Normalized absolute error	.0955	.0402	.0422
Maximum difference	.1444	.2000	.1697
Structural content	1.2296	1.0537	.7295
Correlation	.9999	.9972	.8996

CONCLUSION

From the above output images and the values of quality measures presented in the table 1, it can be concluded that, PCA based image fusion technique can be used for applications which does not require high quality & precision. Whereas DWT based fusion techniques provide us good quality fused images than PCA & DWT based techniques.

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