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A Comparative Analysis of Image Fusion Techniques

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Abstract:**Image Fusion is one of the major research fields inimage processing. Image Fusion is a process of combining the relevant information from a set of images, into a single image, wherein the resultant fused image will be more informative and complete than any of the input images. Image fusion process can be defined as the integration of information from a number of registered images without the introduction of distortion. It is often not possible to get an image that contains all relevant objects in focus. One way to overcome this problem is image fusion, in which one can acquire a series of pictures with different focus settings and fuse them to produce an image with extended depth of field. Image fusion techniques can improve the quality and increase the application of these data. This paper discusses the three categories of image fusion algorithms – the basic fusion algorithms, the pyramid based algorithms and the basicWavelet Transform(WT) algorithms. And also compare the Quantitative function Analysis like Entropy(H), Peak Signal to Noise Ratio (PSNR).It also provides survey about some of the various existing techniques applied for image fusion and comparative study of all the techniques concludes the better approach for its future research.**

*Keywords:**Wavelet Transform, Image Fusion,Principal Component Analysis,Entropy(H), Peak Signal to Noise Ratio (PSNR).*

I. INTRODUCTION

Image Fusion is a process of combining the relevant information from a set of images of the same scene, into a single image, wherein the resultant fused image will be more informative and complete than any of the input images. Input images could be multi sensor, multimodal, multifocal or multi temporal. One of the goals of image fusion is to create a single enhanced image more suitable for the purpose of human visual perception, object detection and target recognition. One of the important pre-processing steps for the fusion process is image registration, i.e., the coordinate transformation of one image with respect to other. Fusion algorithms are input dependent .Image fusion find application in the area of navigation guidance, object detection and recognition, medical diagnosis, satellite imaging for remote sensing, rob vision, military and civilian surveillance, etc.Image fusion systems are widely used in surveillance and navigation applications, for both military and domestic purposes. Image fusion algorithms can be categorized into different levels: low, middle, and high; or pixel, feature, and decision levels. Christo Ananth et al. [14] proposed a method in which the minimization is per-formed in a sequential manner by the fusion move algorithm that uses the QPBO min-cut algorithm. Multi-shape GCs are proven to be more beneficial than single-shape GCs. Hence, the segmentation methods are validated by calculating statistical measures. The false positive (FP) is reduced and sensitivity and specificity improved by multiple MTANN.

The actual fusion process can take place at different levels of information representation. A common categorization is to distinguish between pixel, feature and decision level, although there may be crossings between them. Image fusion at pixel level amounts to integration of low-level information, in most cases physical measurements such as intensity. Generally, the pixel based image fusion methods average pixel intensity values of the source images pixel by pixel which leads to undesired side effects in the

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resultant image. Recently researchers have recognized that it is more meaningful to combine objects or regions rather than pixels. In order to study the differences between various existing techniques comprehensive and comparative study is required. Section 2 describes brief concepts of Image fusion given by different authors whereas in Section 3 we elaborate image Fusion techniques, in Section 4 presents the comprehensive and comparative study among various existing image fusion techniques. During the study we have observe various issues which are summarized with result in Section 5 and conclusion is presented in Section 6.

II. LITERATURE REVIEW

It gives a literature review on some of the existing image fusion techniques for image fusion like, primitive fusion (Averaging Method, Select Maximum, and Select Minimum), Discrete Wavelet transform based fusion, Principal component analysis (PCA) based fusion etc. The purpose of the paper is to elaborate wide range of algorithms their comparative study together. There are many techniques proposed by different authors in order to fuse the images and produce the clear visual of the image. Hierarchical multiscale and multiresolution image processing techniques, pyramid decomposition are the basis for the majority of image fusion algorithms. All these available techniques are designed for particular kind of images. Researchers have shown that fusion techniques that operate on such features in the transform domain yield subjectively better fused images than pixel based techniques. For this purpose, feature based fusion techniques that are usually based on empirical or heuristic rules are employed. Because a general theory is lacking fusion, algorithms are usually developed for certain applications and datasets. To implement the pixel level fusion, arithmetic operations are widely used in time domain and frequency transformations are used in frequency domain. In many applications area of navigation guidance, object detection and recognition, medical diagnosis, satellite imaging for remote sensing, rob vision, military and civilian surveillance, etc., the image fusion plays an important role.

The image fusion, in which one can acquire a series of pictures with different focus settings and fuse them to produce an image with extended depth of field. During the fusion process, all the important visual information found in the input images must be transferred into the fused image without introduction of artifacts. In addition, the fusion algorithm should be reliable and robust to imperfections such as noise or mis-registration. Image fusion is a branch of data fusion where data appear in the form of arrays of numbers representing brightness, color, temperature, distance, and other scene properties. Such data can be two-dimensional (still images), three-dimensional (volumetric images or video sequences in the form of spatio-temporal volumes), or of higher dimensions. In recent years, multivariate imaging techniques have become an important source of information to aid diagnosis in many medical fields. Early work in image fusion can be traced back to the mid-eighties. Burt [1] was one of the first to report the use of Laplacian pyramid techniques in binocular image fusion and later on Burt and Adelson[2] later introduced a new approach to image fusion based on hierarchical image decomposition at about the same time Adelson disclosed the use of a Laplacian technique in construction of an image with an extended depth of field from a set of images taken with a fixed camera but with different focal lengths. Later Toet [3] used different pyramid schemes in image fusion which were mainly applied to fuse visible and IR images for surveillance purposes. Some other early image fusion work are due to Lillquist[4] disclosing an apparatus for composite visible/thermal infrared imaging, Ajjimarang[5] see suggesting the use of neural networks in fusion of visible and infrared images, Nandhakumar and Aggarwal [6] providing an integrated analysis of thermal and visual images for scene interpretation, and Rogers et al. [7] describing fusion of LADAR and passive infrared images for target segmentation. Use of the discrete wavelet transform (DWT) in image fusion was almost simultaneously proposed by Li and Chipman et al. [8] at about the same time Koren et al. [9] described a steerable dyadic wavelet transform for image fusion and also around the same time Waxman and colleagues developed a computational image fusion methodology based on biological models of

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color vision and used opponent processing to fuse visible and infrared images. The need to combine visual and range data in robot navigation and to merge images captured at different locations and modalities for target localization and tracking in defense applications prompted further research in image fusion. Many other fusion techniques have been developed during the last decade. Today, image fusion algorithms are used as effective tools in medical, remote sensing, industrial, surveillance, and defense applications that require the use of multiple images of a scene.

III. IMAGE FUSION TECHNIQUES

The enhancement of Image fusion methods are of two types namely Spatial domain methods and frequency domain methods. In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. The fusion methods, such as averaging, the Brovey method, principle component analysis (PCA), and IHS based methods fall under the spatial domain approaches. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values. Pyramid Fusion Algorithm is a fusion method in the transform domain.

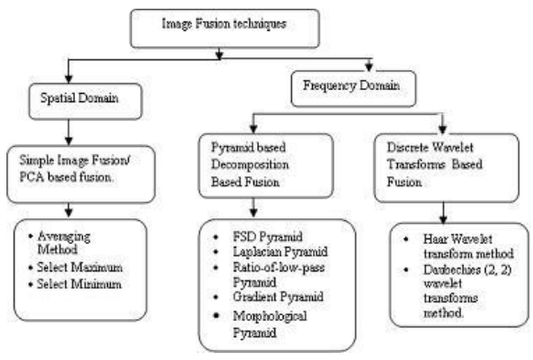

Figure 1.1 Categorization of Image Fusion Techniques

Image Fusion techniques can be sub divided in three different types of techniques including Simple fusion techniques, Principal Component Analysis (PCA) based Fusion, Pyramid based image fusion methods and Discrete Wavelet Transform (DWT) based fusion as shown in figure 1.1 as above.

3.1 Simple Image Fusion/ PCA based fusion

Simple Fusion Algorithms mainly perform a very basic operation like pixel selection, addition, subtraction or averaging shown in Figure1.1 are Average Method, Select maximum, Select minimum, PCA. These methods are not always effective but are at times critical based on the kind of image under consideration. The trivial image fusion techniques studied and developed are average method in which the resultant image is obtained by averaging every corresponding pixel in the input images.

$$I_F=\{abs(I_A),abs(I_B)\}/2.$$

This technique is a basic and straightforward technique and fusion could be achieved by simple averaging corresponding pixels in each input image. The most straightforward way to build a fused image of several input images is performing the fusion as a weighted superposition of all input images.

$$I_F = max\{abs(I_A),abs(I_B)\}.$$

$$I_F = min\{abs(I_A),abs(I_B)\}.$$

Select Maximum/Minimum Method is a selection process if performed here wherein, for every corresponding pixels in the input images, the pixel with maximum/minimum intensity is selected, respectively, and is put in as the resultant pixel of the fused image.

3.2 PCA based fusion

In Principal Component Analysis (PCA) is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. It reveals the internal structure of data in an unbiased way. Principal component Analysis is a mathematical tool which transforms a number of correlated variables into

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a several uncorrelated variables. PCA is widely used in image classification. 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 anaverage of the weighted pixel values to produce the result for the fused image at the same pixel location. The optimal weighted factors are determined by the PCA technique. The PCA technique is useful for image encoding, image data compression, image enhancement, pattern recognition (especially for object detection), and image fusion. It is a statistical technique that transforms a multivariate data set of inter-correlated variable into a data set of new un-correlated linear combinations of the original variables. It generates a new set of axes which is orthogonal. By using this method, the redundancy of the image data can be decreased.

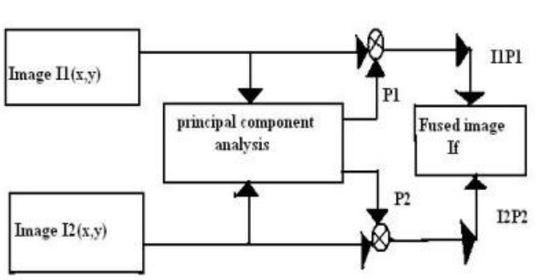

Figure 1.2. Image Fusion Process using PCA

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

$$I_f(x,y)=P_1I_1(x,y)+P_2I_2(x,y)$$

The process flow diagram of PCA algorithm is shown in above figure 1.2. 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.

3.3Wavelet transform

Wavelet theory is an extension of Fourier theory in many aspects and it is introduced as an alternative to the short-time Fourier transform (STFT). In Fourier theory, the signal is decomposed into sines and cosines but in wavelets the signal is projected on a set of wavelet functions. Fourier transform would provide good resolution in frequency domain and wavelet would provide good resolution in both time and frequency domains. Although the wavelet theory was introduced as a mathematical tool in 1980s, it has been extensively used in image processingthat provides a multi-resolution decomposition of an image in a biorthogonal basis and results in a non-redundant image representation. The basis are called wavelets and these are functions generated by translation and dilation of mother wavelet. In Fourier analysis the signal is decomposed into sine waves of different frequencies. In wavelet analysis the signal is decomposed into scaled (dilated or expanded) and shifted (translated) versions of the chosen mother wavelet or function . A wavelet as its name implies is a small wave that grows and decays essentially in a limited time period. A wavelet to be a small wave, it has to satisfy two basic properties:
i) time integral must be zero

$$\int_{-\infty}^{\infty} \psi(t)dt = 0$$

ii)square of wavelet integrated over time is unity

$$\int_{-\infty}^{\infty} \psi^2(t)dt = 1$$

III.IMAGE QUALITY METRICS

The general requirement of an image fusing process is to preserve all valid and useful information from the source images, while at the same time it should not introduce any distortion in resultant fused image. Performance measures are used essential to measure the possible benefits of fusion and also used to compare results obtained with different algorithms.

Peak Signal to Noise Ratio:

The PSNR is use tocalculate the similarity between two images. The PSNR between the reference image R and the fused image F is defined as

$$PSNR(dB) = 10\log_{10}(R^2 / MSE)$$

For better fused image PSNR value should high.

Mean Square Error (MSE):

MSE is a frequently used measure of the difference between original image and fused image pixels. MSE is defined as Image with size of given by below equation,

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$$MSE = \frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left[I_{1(i,j)} - I_{2(i,j)}\right]^2}{m \cdot n}$$

R- Maximum fluctuation in input images,$I_{1(i,j)}$- original image,$I_{2(i,j)}$- Fused image,*n,m* – Row & Column dimension of the image pixels.

Entropy (H):

Entropy is used to calculate theamount of information.

$$E = -\sum_{l=0}^{L-1} P_l \log_2 P_l$$

Higher value of entropy indicates that the information increases and the fusion performances are improved.

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IV. COMPARATIVE STUDY OF VARIOUS IMAGE FUSION TECHNIQUES

On the basis of the study only few comparisons between the different existing fusion techniques have been made and are analyzedMathematically and theoretically which are shown in Table 1 as below.

Fusion Technique/Algorithm	Domain	Advantages	Disadvantages	Fusion Metrics (In Medical Images)	
				Entropy	PSNR
Simple Average	Spatial	Simple in implementation	Resultant fused image is not clear	1.56	14.34
Simple maximum	Spatial	Fused image is highlyfocused image	Blurring effect is more	2.95	19.28
PCA	Spatial	PCA is a tools whichtransforms number ofcorrelated variable intonumber of uncorrelated variables, this property canbe used in image fusion	Spectral degradation is present	3.64	25.32
Combine DWT ,PCA	Transform	Output image containedboth high spatial resolution with high quality spectralcontent	Complex method	3.96	31.35
Combine SWT ,PCA	Transform	To increase time and frequency localization.	Complex method&Shift variant	4.31	34.43

VI. CONCLUSION

This paper performs the Comparative study of Image fusion techniques. Here, various techniques of Image Fusion that are useful in image fusion is to create a single enhanced image more suitable for the purpose of human visual perception, object detection and target recognition has been discussed. On the basis of the study we have find out various issues in different techniques and to remove them various techniques are proposed for fusion of different images. This review presents that which approach is better among all the existing Image results that spatial domain provide high spatial resolution but spatial domain have image blurring problem. The Wavelet transforms is the very good technique for the image fusion provide a high quality spectral content. But a good fused image have both quality so the combination of DWT &PCA fusion algorithm. And also SWT & PCA combination improves the performance as compared to use of DWT and PCA combination algorithm. SWT is to increase time and frequency localization and gives more accuracy. Finally this review concludes that hat a image fusion algorithm based on combination of SWT and PCA with morphological processing

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image fusion.

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