A COMPARATIVE STUDY OF DIFFERENT IMAGE FUSION TECHNIQUES FOR TONE-MAPPED IMAGES

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***Abstract*— Image Fusion is the major research area in image processing. Image fusion is the process in which two or more images are merged into single image which can retain all important features of all original images. Fused image will be more informative and complete than any of the input image. To improve quality of information from a set of images fusion process is used. It is 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 setting 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 presents a review on different image fusion techniques. Image fusion can be processed at three levels such as pixel level fusion, feature level fusion and decision level fusion. There are mainly two types of image fusion techniques which are spatial domain fusion and Transform domain fusion. The techniques such as Principal Component Analysis is a spatial domain technique and Stationary Wavelet Transform, Discrete Wavelet Transform are transform domain technique. The comparison of all the techniques results the better approach for its future research.**

***Index Terms*— Image fusion, Principle Component Analysis, Discrete Wavelet Transform, Stationary Wavelet Transform.**

I. INTRODUCTION

Fusion is a process which can be used to improve quality of information from a set of images. By the process of image fusion the good information from each images is merged together to form resultant image whose quality is superior to any of input images [4]. Many Fusion techniques have been developed that allow the integration of different information sources in order to create a new image that is more suitable for human visual or machine perception. The major objective here is to extract all the useful information from the source image in such a way that no artifacts are introduced that distract the human observers. Assessment of the quality of the fused image is an important issue in image fusion [2]. There are important requirement for image fusion process [4]:

- The fused image should preserve all relevant information from the input images.

-Image fusion should not introduce any artifacts that may distract a human observer vision processing steps.

-In the fused image relevant features and noise should be suppressed to a maximum extend.

-the fusion procedure should be consistent, strong and have the capacity to tolerate imperfections such as noise or miss registration.

In the field of medical imaging remote sensing and machine vision the multi-sensor data may have multiple images of the same scene providing different information. It is not possible to have a single image that contains all the information of objects in the image, so image fusion is required. Major applications of image fusion include remote sensing, medical imaging, microscopic imaging, computer vision and robotics.

II. BASIC LEVELS OF IMAGE FUSION

Image fusion can be done at three levels: Pixel Level Fusion, Feature Level Fusion and Decision Level Fusion [2].

A. Pixel Level Image Fusion

Pixel level method is the simplest and widely used method. It is the low level of fusion. This method processes pixels in the sources image and retain most of the original image information. Pixel-level fusion is done in the phase of image pre-processing. The purpose is to obtain a further clear image, which provides more information. Pixel-level fusion is divided into two parts, signal-level and image-point fusion. Signal-level fusion refers to synthesize a group of signals obtained by sensors in order obtain high-quality signals, whose format is consistent with the original image. In the process of image-point fusion, image points of every image are directly synthesized

B. Feature Level Image Fusion

Feature-level fusion is the medium level fusion and prepared for decision-level fusion. Feature-level fusion is done in the course of image feature extraction. In this, features of every image are extracted and same kind of features of different images is organically synthesized. The typical features are profile, texture, shape, angle, similar lighting area and similar depth of focus area. While fusing features, the contents and forms of main features are correlative with the applied Fusion,

Feature-Level Fusion and Decision-level Fusion [2].

C. Decision Level Image Fusion

Decision-level fusion is the highest-level fusion. All decision and control are taken according to the results of decision-level fusion. It uses the data information extracted from the pixel level fusion or the feature level fusion to make optimal decision to achieve a specific objective.Moreover the redundancy and uncertain information.

The pre-processing steps of image fusion are shown in fig.1. These include image registration, image resampling and combing of the images.

Fig.1. Preprocessing steps for Image Fusion

III. IMAGE FUSION TECHNIQUES

In the image fusion method the required data from the given supply images is merged together to make a composite image whose quality is more advanced than the given feedback images. The simplest way of fusion images is by taking the grayscale average of the pixel of the source images. This simple method gives good results at the cost of reduced contrast level. Image fusion method can be classified into two methods.

- Spatial domain fusion method
- Transform Domain Fusion

The Spatial domain technique is directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. The fusion methods such as averaging, principle component analysis (PCA) and IHS based methods falls under the spatial domain approaches.

In frequency domain method, the image is first transferred into frequency domain. The fourier transform of the image is computed first. All the enhancement operations are performed on the fourier transform of the image and then inverse fourier transform is applied to get the resultant image. The oldest method of colour image fusion is IHS transform. PCA is one of the commonly used method which is similar to the IHS transform. PCA, IHS and high pass filtering methods fall under the category of spatial domain technique. Image fusion technique can be sub divided in three different types of techniques including Simple fusion technique, Principle component analysis(PCA) based fusion, discrete wavelet transform(DWT) based fusion and Pyramid based image fusion as shown in fig.2 as below.

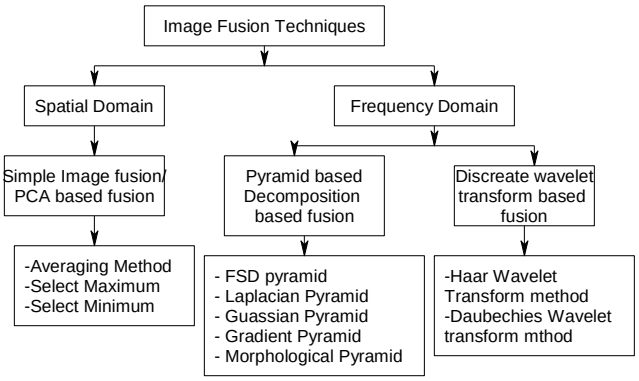

Fig.2. Classification of Image fusion techniques

A. Spatial Domain Fusion Techniques

[1] Average Method

Regions of images which are in focus are of higher pixel level intensity as compare to other regions of images. Average method of fusion is a method of to obtain an output image in which all regions are in focus. Sum of values of pixel (i, j) of each image is done and then divided by total number of input images which results in average value. The average value obtained is given to the correspondingly pixel of the output image. Fast running speed is the main advantages of this method. But the disadvantage is that clear objects are not seen by using this method [13].

[2] Simple Maximum Method

In this image fusion method, the resultant fused image is obtained by selecting the maximum intensity of corresponding pixels from both the input image.

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \max A(i,j)B(i,j)$$

A(i,j), B(i,j) are input images and F(i,j) is fused image. The advantage is that it results in highly focused image output obtained from the input image as compared to average method. The disadvantage is that the pixel level method is affected by blurring effect which directly affect on the contrast of the image.

[3] Simple Minimum Method

In this image fusion method, the resultant fused image is obtained by selecting the minimum intensity of corresponding pixels from both the input image [5].

$$F(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \min A(i,j)B(i,j)$$

A(i,j), B(i,j) are input images and F(i,j) is fused image.

[4] Principle Component Analysis (PCA)

PCA is a technique involving numerical procedure of transforming the correlated variables into uncorrelated variables called principal component. Compact and optimal depiction of the data set is computed. PCA is the simple technique which reveals the internal structure of data in balanced way but it may produce spectral degradation. Application areas for using PCA are image classification and image compression [13].

There's involvement of mathematical formula for change of factors which can be called key components. The First key aspect is taken across the direction of optimum variance and the 2nd key aspect is lay in the subspace at a 90 level angle of the first. Within this Subspace, this aspect items the direction of optimum variance. The next key aspect is taken in the optimum difference direction in the subspace at a 90 level angle to the former two [9]. The major advantage is that it prevents certain features from dominating the image because of their large digital numbers. The disadvantage is that it suffers from spatial degradation.

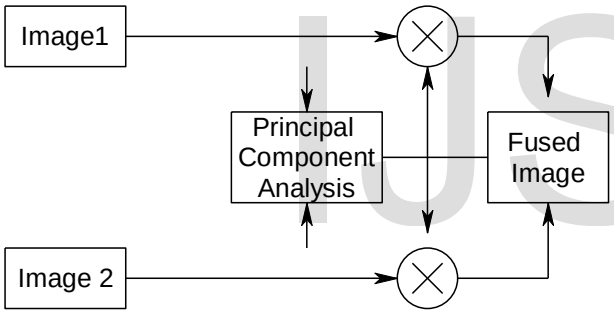

Fig.3. Image Fusion Process Using PCA

[5] IHS Transform

It is most popular fusion methods and used in remote sensing. Intensity, Hue and Saturation are the three properties of a color. The fusion is based on the RGB-IHS conversion model. In this method, the principle is based on the IHS color space which owns the ability to separate the spectral information of an RGB composition in its two components H and S. In this method three MS bands R, G and B of low resolution Image are first transformed into the IHS color coordinates, and then the histogram - matched high spatial resolution image substitutes the intensity image which describes the total color brightness. Finally an inverse transformation from IHS space back to the original RGB space results the fused RGB image which contain spatial details of the high resolution image. This method provides a better visual effect and high spatial quality for the fused image. Limitation of this method is that it produces a significant color distortion with respect to the original image [2].The IHS method is most frequently used fusion method for sharpening.

[6] High Pass Filtering

The high resolution multispectral images are obtained from high pass filtering. The high frequency information from the high resolution image is added to the low resolution multispectral image to obtain the resultant image. It is performed either by filtering the High Resolution Image with a high pass filter or by taking the original HRPI and subtracting LRPI from it. The spectral information contained in the low frequency information of the HRMI (High resolution multispectral image) is preserved by this method. When the low pass filter is used, it shows a smooth transition band along with a high ripple outside the pass band [1].

B. Transform Domain Fusion Techniques

The multi resolution techniques have two types, one is Pyramid transform and other is Wavelet Transform.

[1] Pyramid Transform

It is a fusion method in the transform domain. Various Pyramid based fusion techniques are Laplacian Pyramid, Ratio-of-low-pass Pyramid, FSD pyramid, Gradient Pyramid, Morphological Pyramid can be used for the image fusion using different fusion rules. In pyramid approach, pyramid levels obtained from the down sampling of source images are fused at pixel level depending on fusion rules. The fused image is obtained by reconstructing the fused image pyramid. An image pyramid consists of a set of low pass or band pass copies of an image, each copy representing pattern information of a different scale. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images and then the fused image is obtained by taking inverse pyramid transform[10].The advantage of this method is that it can provide information on the sharp contrast change.

[2] Discrete Wavelet Transform

Wavelet transform is alternative to the short time Fourier transforms. It is advantageous over Fourier transform in that it provides resolution in time domain as well as in frequency domain whereas Fourier transform gives a good resolution only in frequency domain. In Fourier transform, the signal is decomposed into sine waves of different frequencies whereas the wavelet transform decomposes the signal into scaled and shifted forms of the mother wavelet or function. It does not change the information content present in the signal [1].

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 coefficient of the sources images according to the

fusion decision map. By performing the inverse wavelet transform the fused image is obtained. It provide better signal to noise ratio than pixel based approach. In this method the final fused image have a less spatial resolution.

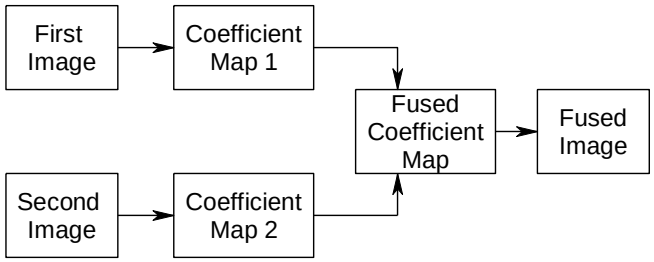

Fig.4. Image Fusion Process Using DWT

[3] Stationary Wavelet Transform

The discrete wavelet transform is not a time–invariant transform. To overcome the disadvantage of DWT i.e it lacks the translation invariance, SWT is developed. Here the process of down sampling is suppressed that means the SWT is translation invariant. SWT is based on the idea of no decimation. It applies the discrete wavelet transform and cancel both down sampling in the forward and up-sampling in the inverse transform. In this algorithm, iterations are primary placed on the particular rows then on the columns to create transform coefficients. Four images produced are of same size as of original image. These transformed coefficients are fused and inverse discrete stationary wavelet transform is applied to form fused image.

[4] Discrete Cosine Transform (DCT)

DWT techniques have number of disadvantages such as they need number of convolution calculations, require more memory resources and take much time. DCT based fusion methods need less energy as compare to DWT. A DCT is used to express a sequence of finite data points in terms of a sum of cosine functions at different frequencies. DCT is an important transform used in digital image processing [6].

The images are divided into three parts as low frequency, medium frequency and high frequency. RGB image is divided into the blocks of size 8*8 pixels. The image is then grouped by the matrices of red, green and blue and transformed to the grayscale image. The 2 Dimensional Discrete Cosine Transform is then applied on the greyscale image. The frequency of the grayscale block is converted from the spatial domain to frequency domain. Once the DCT coefficients are calculated; By applying the fusion rule the fused DCT coefficients are obtained. The fused image is obtained by taking inverse DCT. This method is more reliable in terms of time and hence they are useful in real time systems .Large DCT coefficients are concentrated in the low frequency region. Hence they have excellent energy compactness properties. When the real time data is given as an input, it gives the real results[1].

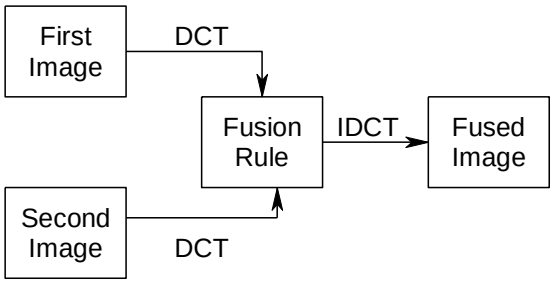

Fig.5. Image Fusion Process Using DCT

IV. CONCLUSION

In this paper different image fusion techniques have been reviewed. The image fusion techniques are used to create a single enhanced image which is more suitable for the purpose of human visual perception, object detection. Each technique has advantages and disadvantages. These techniques improve the clarity of the images to some extent. Spatial domain provides high spatial resolution. The advantage of simple average technique is that it is the simplest method of image fusion; while its disadvantage is that this method does not give guarantee to have clear objects from the set of images. Simple maximum technique gives highly focused image output compared to average method, but its disadvantage is that it gives blurring effect which directly affect on the contrast of the image. PCA technique has good spatial resolution, but produces spectral degradation. In spatial domain spectral distortion is the main drawback therefore transform domain image fusion is done. The transform domain methods provide a high quality spectral content. We have also described the wavelet based fusion of images. But DWT in transform domain is time variant, this problem is overcome by using SWT. In future, the different wavelet based techniques can be merged to form a hybrid fusion technique and the result can be compared.

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