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REVIEW OF IMAGE FUSION TECHNIQUES

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Abstract - ***Image fusion is a procedure of fusing two or more images of same scene to form single fused image which displays vital information in the fused image. Image fusion technique is used for removing noise from the images. Noise is an unwanted material which deteriorates the quality of an image affecting the clarity of an image. Noise can be of various types such as Gaussian noise, impulse noise, uniform noise etc. Images corrupt sometimes during acquisition or transmission or due to fault memory locations in the hardware. Image fusion can be done 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 techniques and temporal domain fusion techniques. Average method, PCA fusion, high pass filtering are spatial domain methods and methods which include transformation such as Discrete Cosine Transform, Discrete wavelet transform are temporal domain fusion methods. There are various methods of image fusion which have many advantages and disadvantages. Many techniques suffer from the problem of color artefacts that comes in the fused image formed. In this paper different techniques have been reviewed and the main objective is to find the shortcomings that occur in different image fusion techniques.***

Key Words: *Image fusion, PCA, Discrete Cosine Transform*

1. INTRODUCTION

Image fusion is a technique in which multiple images of same scene from visual sensor networks are fused together to form single fused image. It extracts the relevant information from input images and highlights the useful information and important features in the fused image without introducing inconsistencies in this image. Visual sensor networks is a network formed of spatially distributed cameras which are processes and fuses multiple images of scene from different viewpoints into a single image. The network also contains central computers which are capable of processing and fusing the image data obtained from multiple cameras.

A single image cannot focus on all the objects in a scene in many situations thus multi-focus image fusion technique is used which fuses several images of scene captured with focus on various objects using different sensors and then these images are fused to from a resulting image which focus all the objects in the scene. In fig. 1, camera has focused on left side of image and its right side has been shown blurred. In fig. 2, camera has focused on right side of image and its left side has been shown blurred. Both these images are fused to form resultant image as shown in figure 3 which contain more information than the single source image [7].

Fig. 1 Image focused on left

Fig. 2 Image focused on right

Fig. 3 Fused Image

2. LITERATURE SURVEY

Phamila and Amutha (2013) [10] has shown that multi focus image scheme, , based on higher highly valued alternating coefficients (AC) worked out throughout Discrete cosine change (DCT), is usually a uncomplicated and efficient plan pertaining to cellular image sensor devices built with learning resource limited, battery pack driven graphic receptors utilized in security and high-risk atmosphere including battlefields for example because complex arithmetic floating point operations like mean or variance calculations are not used in this method. AC-DCT method overcomes the actual calculation and power limitation of low power devices.

Li and Dong (2013) [7] has discussed pixel level image fusion. Pixel level image fusion describes the particular processing along with synergistic combination of information collected coming from source images which offers improved perception of a scene.. The demand for significant and spatial correct combination of all available image datasets arises with the development of sensors. Pixel level image fusion technique can be applied in many application areas such as in machine vision, airborne and space borne remote sensing and medical imaging etc.

Sharmila et al. (2013) [4] has shown that multimodality medical image fusion using discrete wavelet transform and entropy concepts provides better quality of information and less noise in the fused image formed. Medical image fusion is the s the technique of deriving very important data simply by incorporating multimodality medical images like computed tomography (CT), Magnetic resonance imaging (MRI), Positron emission tomography (PET) and single photon emission computed tomography (SPECT) into single image . The information thus derived can be used for various purposes such as for diagnosing diseases, detecting tumour, surgery treatment etc. Single modality image cannot provide this useful information.

Li et al. (2013) [9] has shown that region based multi-focus image fusion using the local spatial frequency in spatial domain performs better in terms of both image quality and objective evaluation as compare to pixel-based image fusion methods. Pixel-based image fusion methods are generally subject to defects connected with source images which influence the quality of fused image. Region based multi-focus image fusion method using local spatial frequency first segments the average image of source images to get the region map and then calculates local spatial frequency for each pixel in source images from a local window. After this, regional spatial frequency is calculated for each region. Then a fused image is constructed from the selected regions according to the RSF calculated.

Ganesh et al. (2007) [5] has discussed techniques of image fusion to remove noise from digital images. Remote sensing plays a very essential role in satellite communication. Satellite produces images in digital format which are corrupted during acquirement, transmission or due to wrong memory locations in hardware. The density of noise varies depending on various factors such as atmospheric variations and noise communication channels etc. It is important to remove the noise from images for further processing. Images captured by different sensors produce different impulse noise images and for removal of impulse noise, median filters are used. Firstly noisy images are filtered using various types of vector median filters and then these filtered images are combined to form single image by image fusion technique relying on the quality assessment in spatial domain. Then fused image formed is again filtered using absolute derivation vector median which gives more noise free image.

Liu et al. (2013) [6] has shown that multi-focus image fusion strategy based on the lifting scheme of wavelets gives substantial information in the fused image. This technique is fast in speed which takes less memory and is easier to implement. In this technique input images are decomposed into four sub-bands- LL, LH, HL and HH. Sub-bands LL, HL and HH are synthesized to have several guidelines regarding high-frequency details of images. Weighted area energy is usually determined with the Gaussian kernel based on the high frequency details. A binary map is obtained by deciding the highest energy between images. At last, sub-bands LL, LH, HL, HH are synthesized to obtain fused image.

Jasmeet and Rajdavinder (2014) [3] has discussed different image fusion techniques. Image fusion is the process of incorporating the details through different images of a single scene into single image which is more appropriate for human visualization and additional image processing. Image fusion techniques based on Discrete cosine transform (DCT) domain are fit to provide valuable information in fused image and is time conserving in real-time systems for still images or videos.

Zhang and Cao (2013) [2] has shown that medical image fusion technique according to wavelet theory is usually fast as well as perfect fusion. Image processing, image registration and image fusion are the main three steps included in this approach. Image processing acquire all over multi image resolution attributes associated with wavelet to completely clean off noise. Image registration cross the wavelet analysis to gain biggish change position as well as acquire impression side to obtain swift as well as good image registration . Image fusion is done to save all information to have a perfect fusion.

Malhotra and Chopra (2014) [1] has shown that multi-focus image fusion using AC-DCT (Alternating coefficient discrete cosine transform) technique has the ability to preserve edges of the fused image and it will also remove the uneven illuminate problem which occurs in fusion of images. DCT based fusion requires less energy as compare to DWT techniques and are more suitable for resource constrained devices.

Prakash et al. (2013) [8] has shown that pixel level image fusion scheme using multi resolution biorthogonal wave transform (BWT) makes fusion features better by reducing loss of valuable information available in individual images. Spatial domain techniques for fusion produces spatial distortions in the fused image. Wavelet transform based methods can handle these distortions. In BWT, Wavelet coefficients at different decomposition levels are fused using absolute maximum fusion rule. Wavelet symmetry and linear phase of BWT are the two properties of filters used in fusion which preserves the edge formation, lines, curves and boundaries in the fused image and hence reduce distortions in the fused image.

Devaki and Rao (2014) [11] has discussed image fusion technique to protect the secret image whose confidentiality has to be maintained and authentication of the distributor has to be done who distributes the secret image to multiple users. Fusion of the finger print of the dealer has been done with the secret image which makes single fused image. Threshold secret sharing technique divides the fused image into number of shares with the threshold value which provides confidentiality of the secret image as well as authentication of the dealer who has sent the image. Reconstruction of secret image is done for verification.

Galande and Patil (2013) [12] has discussed about medical image fusion to improve the content of an image by fusing images taken from different imaging tools such as computed tomography, magnetic resonance imaging, positron emission tomography and single photon emission computed tomography. Different image fusion approaches based on pixel level image fusion and transform dependent image fusion has been discussed and then comparison has been made among these techniques based on the limitations and advantages of each method.

Garg et al. (2014) [13] has discussed multi-focus image fusion algorithms which brings together distinct images acquiring distinct elements throughout focus.. It has been found that pixel based image fusion algorithms possesses some problems like blurring effects and noise in the fused image. Region based image fusion approaches solve these problems but are more complex than pixel based image fusion algorithms. Spatial domain methods are shift-invariant and does not cause loss of information as compare to frequency domain methods.

Fan et al. (2014) [14] has discussed the nonlinear weighted multiband fusion algorithm. The traditional method of image fusion has large amount of calculation and poor real time performance. As compare to traditional method nonlinear weighted algorithm of image fusion improves the effect of image fusion and also enhances the efficiency of image fusion.

Wang et al. (2013) [15] has explained multi-spectral image fusion algorithm. Multi-spectral and panchromatic images are fused together to form fused image. Nonsubsample contourlet transformation method for extracting space detail information of panchromatic image is combined with injection model of panchromatic image to form fused image with multi spectral fusion algorithm. By this method spectral characteristics of multi spectral image are retained and spectral distortion problem is also reduced.

Yang and Liu (2013) [16] has discussed medical image fusion which is used in medical image treatment and diagnosis. It can be applied to various medical fields such as medical diagnosis and therapy, computer assistant medical diagnosis, long distance medical diagnosis and therapy etc. Digital image fusion is a comprehensive information of number of source images inorder to obtain more accurate and more reliable information of the source which helps in good understanding of an image. Medical image fusion process has been discussed.

3. Image Fusion Techniques

There are three levels of image fusion which are pixel level, feature level and decision making level. Pixel level image fusion is related to the pixel location which combines the visual information from input images into single image based on the original pixel location. Feature level image fusion use various features like regions or edges and combines source images according to these features to form a fused image. Decision level fusion techniques merge image details directly such as in the form of relational graphs. Pixel level fusion preserves more significant information as compare to feature level and decision level fusion.

There are mainly two types of image fusion methods which are

- Spatial domain fusion.
- Temporal domain fusion

Spatial domain combination offers mostly with the pixels of origin graphics. It fuses entire graphics utilizing local spatial features including gradient, spatial volume as well as local common deviation. Temporary domain combination consists of your shift of entire graphics straight into frequency domain. In this approach source images tend to be projected on to locaized bases which are designed to stand for your sharpness as well as edges associated with an image. Most of these converted coefficients help in extracting pertinent features from input images to form fused image.

3.1 Spatial domain fusion techniques

- Average Method
- Principal Component Analysis
- IHS Transform
- High Pass Filtering

Average method

Regions of images which are in focus are of higher pixel level intensity as compare to other regions of images [3]. 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.

Principal Component Analysis (PCA)

PCA is a technique involving numerical procedure of transforming the correlated variables into uncorrelated variables called principal components[7]. 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.

IHS Transform

Intensity, Hue and Saturation are the three properties of a color that give controlled visual representation of an image. In the IHS space, hue and saturation need to be meticulously controlled because it contains almost all of the spectral data. In the process of fusion of high resolution panchromatic (PAN) image and multispectral images, the actual aspect data associated with high spatial resolution is added to the spectral information. IHS technique is based on a principle of replacing one of the three ingredients (I, H or S) of one data set with another image. Mostly the actual high intensity route is actually replaced. IHS transform is done on the low spatial resolution images and then the intensity ingredient is replaced by the high spatial resolution image. Reverse IHS transform is applied on new set of ingredients to form the fused image. The IHS technique is one of the most frequently used fusion method for sharpening.

High Pass Filtering

The low spatial resolution image is incorporated by means of statistical functions such as subtraction, addition, multiplication or ratios, with the spatial information received using high pass type filtering on the high spatial resolution image. The high frequency information from the high resolution panchromatic image is added to the low resolution multispectral image to obtain the resultant

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image. It is performed either by filtering the High Resolution Panchromatic Image (HRPI) with a high pass filter or by taking the original HRPI and subtracting LRPI(Low Resolution Panchromatic Image) from it. The spectral information contained in the low frequency information of the HRMI (High resolution Multispectral Image) is conserved 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 [4].

3.2 Temporal domain fusion techniques

- Discrete Wavelet Transform
- Stationary Wavelet Transform
- Discrete Cosine Transform

Discrete Wavelet Transform (DWT)
Discrete wavelet transform is based on wavelet idea in which the transformation is expected upon set of wavelet functions[2]. It provides good resolution both in time domain and frequency domain. It uses low pass filters and high pass filters. Wavelets use scaling and translation operations. In this method, input images are decomposed into two sub-bands like low sub-bands and high sub-bands using wavelet transform and then these sub-bands are fused using fusion methods available. At the last, inverse wavelet transform is applied on the fused coefficients of low sub-bands and high sub-bands to form the resultant image.

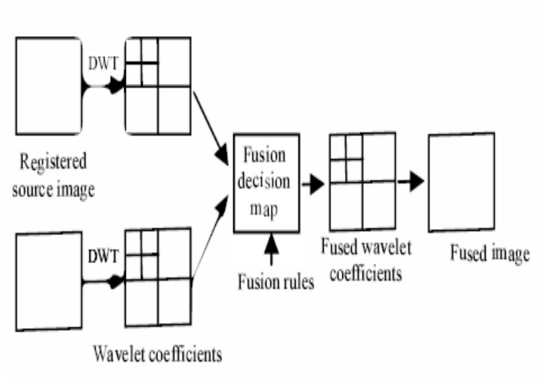

Fig. 4 Image fusion using DWT [2]

Discrete Wavelet Transform averaging entropy Principal component analysis method
It includes three steps –
1. Discrete wavelet transform with average and maximum fusion method to obtain one fused image.
Input images are first subdivided into low sub-bands and high sub-bands using discrete wavelet transform. These low sub-band coefficients and high sub-band coefficients are fused using maximum selection method. Inverse discrete wavelet transform is then applied to fused coefficients and resultant image is generated.
2. Principal component analysis fusion method to obtain second fused image.
In this step, PCA fusion techniques are applied on the same input image and second fused image is formed.
3. Discrete wavelet transform with entropy and maximum fusion method to obtain resultant image.
In this step output of first two steps i.e. two fused images formed are considered as input images and these are decomposed into low sub-bands aand high sub-bands. Low sub-bands are fused using entropy method and high sub-bands are fused using maximum selection method. Now, inverse dicrete wavelet transform is applied on these bands so as to form the resultant fused image[3].

Discrete Stationary Wavelet Transform (DSWT)
DWT lacks the translation invariance thus stationary wavelet transform is developed to overcome this. DSWT removes the down-samplers and up-samplers in DWT and up-sample particular filtration by simply inserting zeroes in between to separate out coefficients. In this algorithm, filters 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 but resolution is half as compare to the original image. These transformed coefficients are fused and inverse discrete stationary wavelet transform is applied to form fused image.

Discrete Cosine Transform (DCT)
DWT techniques have number of disadvantages such as they need number of convolution calculations, require more memory resources and takes much time, which hinder its applications for resource constrained battery powered visual sensor nodes[7]. DCT based fusion methods need less energy as compare to the DWT techniques thus it is appropriate to use DCT fusion methods for resource constrained devices. As computational energy required is less than the transmission energy, data is compressed and fused before transmission in automated battlefields where the robots collect image data from sensor network. In this technique input images and fused images both are coded in JPEG (Joint Photographic Experts Group) format. Contrast sensitivity method is used to form the fused image. The contrasts of the consequent AC (Alternating current) coefficients of different blurred images are compared and the AC coefficient having the largest value is particularly chosen as the AC coefficient for the image formed after fusion. DCT representation of the fused image is found by calculating the average of all the DCT representations of all the input images but it has unwanted blurring effects which decreases the quality of the fused image.

Fusion based on variance
Multi-focus image fusion based on variance calculated in DCT representation can be used to overcome the blurring effect coming in the fused image but the mean, contrast

and variation calculation for the fusion process involves complex floating point arithmetic operations which sustain high energy consumption in resource constrained battery powered sensor nodes.

AC_max fusion
Another multi focus image fusion technique which is suitable for resource constrained is AC_max fusion method. In this method, input images are divided into blocks which are of size 8*8 and the DCT coefficient of each block is computed. Transformed blocks with higher valued AC coefficients are then absorbed into the fused image. Consistency verification of fused blocks is performed and after that fused DCT coefficients can be easily saved or transmitted in JPEG format. Inverse DCT is applied onto the fused DCT coefficients to reconstruct the original fused image[1].

Advantages of AC_max fusion technique are –

- It does not include complex floating position math operations like mean or variance computation which were involved in other techniques and thus it is fast method.
- The fused image formed is of good quality .
- It is performed in DCT domain so it is period protecting in addition to simple if the fused iimage should be preserved or transmitted inside JPEG data format..

4. GAPS IN LITERATURE

It has been found by conducting a review that the most of the present methods does not focus on minimum one of the following things -

1. The majority of the existing approaches rely upon transformations therefore some color artefacts may occur which may decrease the performance of the transform based vision fusion techniques.
2. It has been observed that the problem of the uneven illuminate has not been taken into account in majority of existing techniques.
3. Gray scale images are in focus in most of the existing work instead of color images.

5. CONCLUSIONS

In this paper different image fusion techniques have been reviewed. Each technique has its own advantages and disadvantages. These techniques improve the clarity of the image to some extent but it has been found that most of the techniques suffer from the problem of color artefacts and roughness of edges of the image. In the future work DCT fusion technique will be integrated with gray world based color correction algorithm to remove color artefacts in the image and sobel based gradient optimization algorithm to overcome the problem of degradation of sharpness of edges in the image and then comparison between the results of this integrated approach with DCT fusion technique will be made.

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