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A Literature Review on Spatial and Frequency Domain Image Fusion Techniques

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ABSTRACT

The process of combining the relevant information of multiple images to obtain the single image of improved quality and applicability is called image fusion. This process is extensively used in various application of image processing such as medical imaging, remote sensing, satellite imaging,in design of intelligent robot etc. This paper presents the review of the literature work done by the different authors or researchers to get improved quality of single image by using the essential information from the multiple images. We also discuss about the some image fusion techniques such as averaging, Brovery, PCA etc. with their merits and limitations.

Keywords:Averaging, Brovery, Image Fusion, PCA,Spatial Domain and Frequency domain.

I.INTRODUCTION

With the development of multiple types of biosensors, chemical sensors, and remotesensors on board satellites, more and more data have become available for scientificresearches. As the volume of data grows, so does the need to combine data gathered fromdifferent sources to extract the most useful information. Different terms such as datainterpretation, combined analysis, data integrating have been used. Since early 1990's,"Data fusion" has been adopt and widely used. The definition of data fusion/imagefusion varies.

Image fusion [1] is a process of combining images, obtained by sensors of different wavelengthssimultaneously viewing of the same scene, to form a composite image. The composite image isformed to improve image content and to make it easier for the user to detect, recognize, andidentify targets and increase his situational awareness. Here fig. 1shows the various stages of image fusion process.

Image fusion has been used in many application areas. In remote sensing and in astronomy, multisensory fusion is used to achieve high spatial and spectral resolutions by combining images from two sensors, one ofwhich has high spatial resolution and the other one high spectral resolution. Numerous fusion applications have appeared in medical imaging like simultaneous evaluation of CT, MRI, and/or PET images. Plenty ofapplications which use multisensor fusion of visible and infrared images have appeared in military, security,and surveillance areas.

Multi-view, multi-modal, multi-temporal and multi-focus are the four ways in which image fusion can be performed. Mono modal images captured at the same time but from various viewpoints can be fused multi-view fusion methods. Multi-modal fusion is performed on images captured using various sensors. Multi-temporal fusion is performed on images of the same scene but captured at different times. Multi-focus fusion is performed on images captured with various focal lengths. Image fusion has been used in many applications. Image fusion is widely used in remote sensing. In satellite images are of two types: Panchromatic images and Multispectral images. Using fusion these two images can be merged to produce a single high resolution multispectral image.There are three levels of image fusion which are pixel level, feature level and decision making level [2]. 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.This paper presents the literature study of the image fusion work done by the different researchers. It also discuss some techniques of image fusion with their merits and demerits.

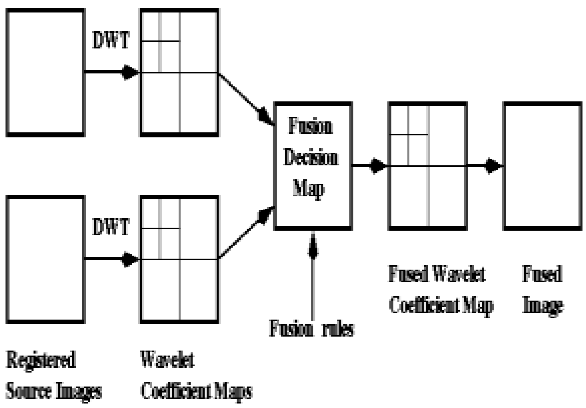

Fig. 1 : Process of Image Fusion

II.RELATED WORK

This section gives an extensive literature survey on the previous work done in the field of image data compression. We study various research and journal paper related to image data compression using DWT. Most of the paper faced as same problem in the fusion process of image data. Some of review of summary given here with entailed with respective authors.

Vani M, Saravanakumar S (2015). In this paper, the multi focus images and multi modalimages to be fused are decomposed by Dual tree discrete wavelettransform (DTDWT). DTDWT coefficients from two sourceimages are fused by electing average of the approximationcoefficients and maximum of the detailed coefficients. Fusedimages are obtained by taking inverse DTDWT. Then multi focusfused image with various parameters like Entropy, Peak Signalto noise ratio (PSNR), Root Mean Square Error (RMSE) arecalculated followed by multi modal fused image Entropy,Standard Deviation, Fusion Factor (FF), Fusion Symmetry (FS)are calculated. Fuzzy Local Information C- Means algorithm(FLICM) is implemented on the multi modal fused images whichis the improved version of FCM (Fuzzy C Means) algorithm.From the segmented classes, tumor is perfectly identified.[3]***Bhavana. V, Krishnappa. H.K (2015).*** In this work, MRI and PET images are pre-processed along with enhancing the quality of the input images which are degraded and non-readable due to various factors by using spatial filtering techniques like Gaussian filters. The enhanced image is then fused based on Discrete Wavelet Transform (DWT) for brain regions with different activity levels. The system showed around 80-90% more accurate results with reduced color distortion and without losing any anatomical information in comparison with the existing techniques in terms of performance indices including Average Gradient and Spectral Discrepancy, when tested on three datasets - normal axial, normal coronal and Alzheimer's brain disease images.[6]***Lan et al. (2014).*** In this article, a multimodal medical image fusionmethod based on wavelet transform (WT) and human visualsystem (HVS) is presented. The proposed image fusion schemecombines the advantages of the WT and the HVS to obtain betterfusion results. The source medical images are first decomposedby WT and utilize HVS to select coefficients. Finally, inverse WTis applied to get the fused image. Some performances are used toevaluate the result.[4]***Daneshvar et al.(2015).***Presented a new method based on lifting scheme is suggested to fuse modals of MR. In this algorithm, lifting wavelet transform is used to decompose source images into different sub-bands. Different fusion rules are applied to fuse sub-bands and achieve fused image. Numerical and visual analyses prove efficiency of propped method in gathering complementally information of source images in one image.[7]***Aishwarya et al. (2016).***Proposed a novel fusion algorithm based on Discrete Wavelet Transform (DWT) and Sparse Representation (SR) is proposed. Initially, DWT is applied to extract the low frequency components and high frequency components of source images. High frequency components are merged using SR based fusion approach and low frequency components are combined using variance as activity level measurement. Finally, inverse DWT is performed on the fused coefficients to get the fused image. Experimental results demonstrate the effectiveness of proposed method in terms of visual perception and quantitative analysis.[8]***Nirmala Paramanandham, Kishore Rajendiran (2016).*** In this, a simple and competent image fusion algorithm based on standard deviation in wavelet domain is proposed and compared with both transform domain as well as spatial domain techniques. The techniques are evaluated with various databases quantitatively and qualitatively.[9]***Chattejee et al.(2017).*** In this paper, a novel and enhanced image fusionprocedure based on Discrete Wavelet Transform (DWT) withArtificial Bee Colony Optimization (ABC) termed as DWTopti isprojected. This method is mainly based on Visual and Infraredimage fusion, which is not only a very tough work to identify finepoints information from a visual image because of light variation,manifestation etc, but also for infrared image, it is very energysensitive in night. To detect or to track an object the fusion isdone. The main object is to get more data from two or more datain a single one which contains maximum information from thoseinput data. Here, for comparing the image quality of theresultant fused image with the input images Structural SimilarityIndex Measure (SSIM) is used and the result is compared withother standard methods of image fusion based on severalconventional methods of Discrete Cosine Transform (DCT) andDWT. [5]***Zhang et al. (2015).*** In this paper, proposed an efficient image fusion algorithm which combined with the advantage of space domain and transform domain. They employ the Principal Component Analysis (PCA) in the low frequency domain, and combine the biggest value selection method with weighted mean method in the high frequency domain. Finally, the output image is obtained by inverse wavelet transform. The experimental results show that this algorithm can produce high-contrast fusion images that are clearly more appealing and have more useful information than the PCA and the wavelet transform.[10]***Mini et al. (2015).***Utilized Stationary Wavelet Transform (SWT), modulus maxima and high boost filtering. The image is decomposed using SWT and its modulus maximum is determined. A fraction of the high pass filtered image obtained as the result of SWT decomposition and modulus maxima is added to original image. The scheme is evaluated visually and objectively using measures like contrast, PSNR etc. The performance measures are evaluated for different category of images and found to be suitable to all categories of mammographic images.[11]***Sonam et al.***In this paper, a novel image fusion algorithm based on discrete wavelet transform (DWT) and cross bilateral filter (CBF) is proposed. In the proposed framework, source images are decomposed into low and high frequency subbands using DWT. The low frequency subbands of the transformed images are combined using pixel averaging method. Meanwhile, the high frequency subbands of the transformed images are fused with weighted average fusion rule where, the weights are computed using CBF on both the images. Finally, to reconstruct the fused image inverse DWT is performed over the fused coefficients. The proposed method has been extensively tested on several pairs of multi-focus and multisensor images. [12]***S. Anbumozhi, P.S. Manoharan (2014).***Focused to classify the brain image into normal and abnormal image using minimum distance classifier algorithm. The proposed methodology consists of spatial domain filter, fusion, clipping circuit and minimum distance classifier algorithm. The difference features are extracted from fused image and compared with trained extracted feature set. The low power architecture for the proposed brain image classification method is presented in this paper. The proposed hardware architecture consumes power of 151mW in CMOS 90nm technology.[13]

III.IMAGE FUSION TECHNIQUES

There are various image fusion techniques which enhance the quality of image by merging two or more image such as PCA, IHS, Averaging, DCT, DWT etc. The fusion techniques are classified in two categories frequency domain and spatial domain. The frequency domain techniques are further classified into subcategories such as Pyramid decomposition based and Discrete transform based. The examples of frequency domain techniques are Laplasian pyramid, DWT etc while example of spatial domain are Average, HIS, Maxima, PCA etc.

3.1 Spatial Domain Techniques

In Spatial field method we simply deal with pixels andmold the pixels to get fused resultant image. While pixelimage fusion methods repeatedly guide to nonexistenceof spectral information and introduce spatialalterations. It includes many algorithms like Simpleaverage, select maximum, select minimum, PCA etc.

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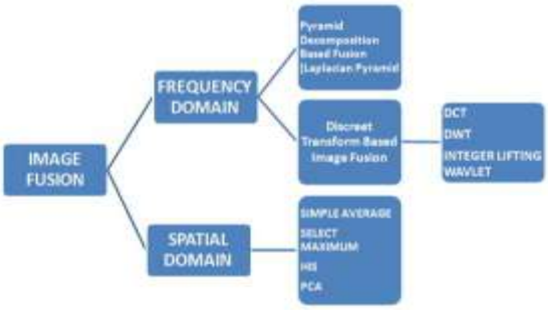

Fig. 2 Classification of Image fusion technique

3.1.1Select Maxima and Minima Method

Basically average method is simple technique in whichall relevant objects are in focus. In this value of everypixel for image is taken and then obtained result isdivided by number 2. Mean value is allocated to everyequivalent pixel.But in select maximum and minimum method selectsthe focused region from the source images by obtainingthe highest value for each pixel and hence results thefocused output. Quality of focused image is based onpixel value. Image will be highly focused if pixel valuewill be higher Pixel value of every image is comparedwith each other and the highest value is allocated topixel.[14]

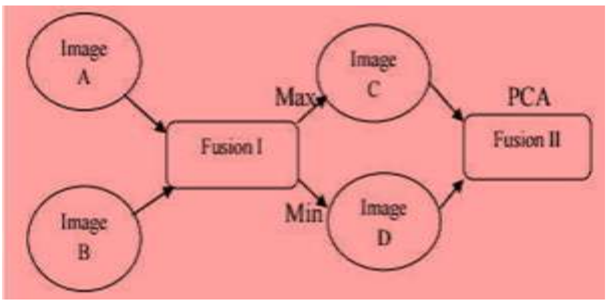

Fig. 3 Select maxima and minima method of image fusion

3.1.2Simple Average Method

It is the simplest method of image fusion technique. In this fused image is obtained by averaging the input pixels. The region of images which are in focus has higher pixel intensity. Thus with the help of this algorithm we can obtain an output image with all regions in focus [15][16]. The value of the pixel P (i,j) of source images are added and divided by 2 to obtain average value which is assigned to the corresponding pixel of output image using equation (1). The same process is repeated for all pixel values.

$$f(i,j) = {\{X(i,j) + Y(i,j)\}}/{2} \quad \text{.........(1)}$$

Where X (i, j) and Y (i, j) are two input images.

3.1.3Principal Component Analysis (PCA) Method

PCA is a powerful technique for extracting structurefrom either high dimensional dataset [17]. This can beperformed by solving Eigen value problem or usingiterative algorithms to estimate the principalcomponents. It is considered as an orthogonaltransformation in which the data will be described whereused to transform a set of correlated variables into a setof uncorrelated variables. The new dataset values arecalled principal components. The number of principalcomponents present after using PCA is either having thesame number or lesser than the present originalvariables. In PCA, the largest possible variance can befound in the first component. PCA becomesindependent if the dataset is distributed jointly, and alsosensitive to the scaling of original variables.[18] Normally,basic PCA uses linear transformations to map data froma high dimensional space of low dimensional space. Thelow dimensional space can be determined byEigenvectors of the covariance matrix.

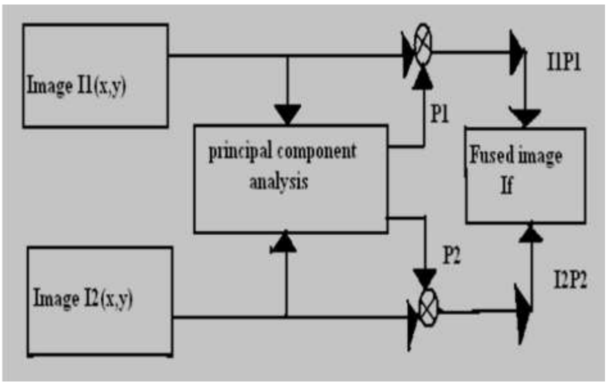

Fig. 4 Principal Component Analysis for Image Fusion

3.1.4 IHS Fusion Method

The IHS technique is one of the most commonly used fusion techniques for sharpening. It has become a standard procedure in image analysis for color enhancement, feature enhancement, improvement of spatial resolution and the fusion of disparate data sets [19]. In the IHS space, spectral information is mostly reflected on the hue and the saturation. From the visual system, one can conclude that the intensity change has little effect on the spectral information and is easy to deal with. For the fusion of the high-resolution and multispectral remote sensing images, the goal is ensuring the spectral information and adding the detail information of high spatial resolution, therefore, the fusion is even more adequate for treatment in IHS space
[20].

3.1.5Brovey Fusion Method

Brovey,[21] is also called the color normalization transform because it involves a red-green-blue (RGB) color transform method. The Brovey transformation was developed to avoid the disadvantages of the multiplicative method. It is a simple method for combining data from different sensors. It is a combination of arithmetic operations and normalizes the spectral bands before they are multiplied with the panchromatic image. It retains the corresponding spectral feature of each pixel, and transforms all the luminance information into a panchromatic image of high resolution. The formula used for the Brovey transform can be described as follows :

Red = (band1/Σ band n)* High Resolution Band

Green = (band2/Σ band n)* High Resolution Band

Blue = (band3/Σ band n)*High Resolution Band

High resolution band = PAN

3.2 Frequency Domain Techniques

In frequency domain method images are decomposedinto multiple scales and transform coefficients aremerged together according to specific fusion rules.Finally, the fused image is constructed with inversetransform of the fused coefficients. In this domainalgorithms based on wavelet approaches are verysuccessful. It includes many algorithms like DWT, SWT,DCT, LWT etc. In comparison of DWT, DCT, DFCTalgorithms LWT is better because of its high speed ofcomputation, energy consumption and high fusedquality.

3.2.1Laplasian Pyramid

In this technique pyramid decomposition is done on each input image and after that fused image is reconstructed by performing inverse pyramid transform. Image pyramid are basically the collection of low or band pass copies of an input image in which both the band limit and sample density are reduced at each step of decomposition [22]. Fused image produced by this technique can further be used for more tasks like segmentation, object detection.

3.2.2Integer lifting wavelet transform

Till now, existing fusion rules are applicable only for fusion of two images. Therefore, fusion algorithm of multiple images based on fast integer lifting wavelet transform is used. This technique is used to calculate wavelet transform as it is faster implementation of wavelet transform. Since earlier techniques involves floating point operations which introduces rounding error due to floating point arithmetic whereas lifting scheme allow us to implement reversible integer wavelet transform.

3.2.3Discrete Wavelet Transform

Wavelet changes are multi-determination picture decay instrument that give an assortment of channels speaking to the picture highlight by various recurrence sub bands at multi-scale. It is a well-known strategy in examining signals. At the point when decay is played out, the guess and detail segment can be isolated 2-D Discrete

Wavelet Change (DWT) changes over the picture from the spatial area to recurrence space. As appeared in fig.5 the picture is isolated by vertical and flat lines and speaks to the primary request of DWT, and the picture can be isolated with four sections those are LL1, LH1, HL1 and HH1[23].

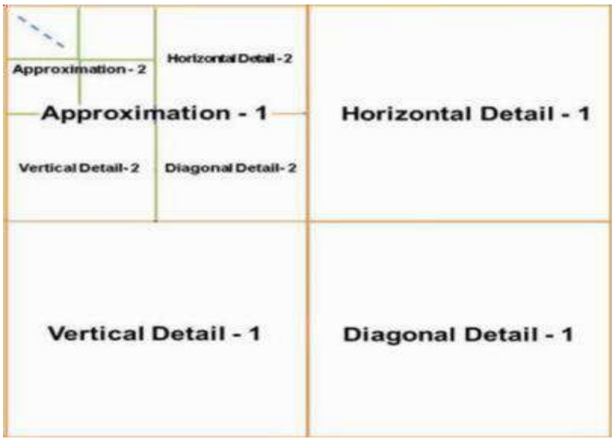

Fig. 5 Wavelet Decomposition

General process of image fusion using DWT [23]: Fig. 6 shows the process of image fusion using DWT.

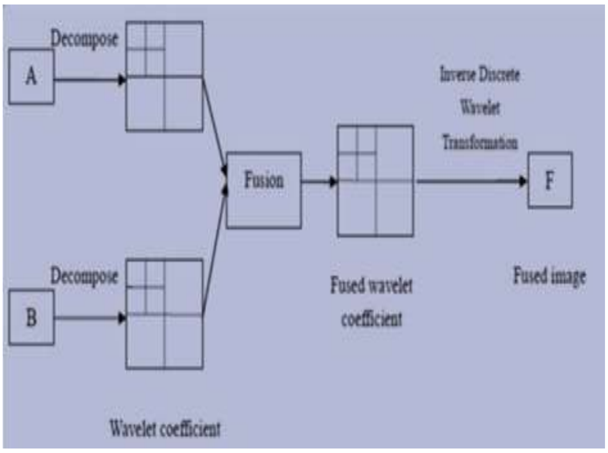

Fig. 6. Wavelet based Image Fusion

Step 1: Execute Discrete Wavelet Change on both the info picture to make wavelet bring down deterioration.

Step 2: Meld every disintegration level by utilizing distinctive fusion run the show.

Step 3: Convey Backwards Discrete Wavelet Change on melded decayed level, which intends to remake the picture, while the picture remade is the intertwined picture F

3.2.4Discrete Cosine Transform

This technique is comparable to discrete Fouriertransform. But DFT is not suitable for non-stationarysignals. In this sine waves are not localized in time andspace. Therefore wavelet method is introduced. DCT candivide the image into sub-bands. It can change thesignals from spatial to frequency domain.[24, 25]

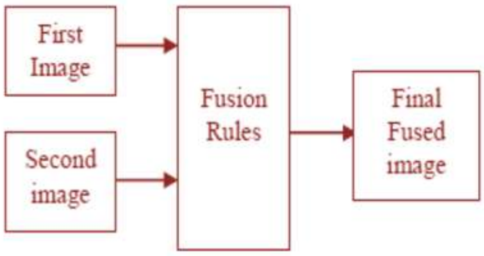

Fig. 7 Image Fusion using DCT

IV.CONCLUSION

In image processing technology, the use of image information is increasing but it becomes very essential that the images must provide improved information. So to recover better quality of image various image processing has evolved. In this image fusion technology is used to get improved quality of image. This paper presents the literature work perform by various researcher together with some fusion techniques such as HIS, averaging, DWT, DCT etc. After studying it is found that the some techniques are more effective to provide better image quality but they are complex to design and consuming much processing time. So in future need to design such technique or algorithm which is less time consuming and also give improved result.

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Table 1: Advantage and Disadvantages of Image fusion techniques

Techniques	Advantages	Disadvantages
Select Maxima and Minima	Resulting in highly focused image output obtained from the input image as compared to average method	1. This technique is pretentious from blurring effect which directly alters the contrast of image 2. Pixel level method are affected by blurring effect which directly affect on the contrast of the image
Simple Averaging	1. Easy to use and implement 2. Fast processing speed	This technique reduces the resultant image quality by introducing noise into the fused image
Brovey Method	1. It is straightforward and simple 2. computationally efficient and faster processing time	1. Alters the spectral information of the original image 2. It leads to undesirable side effect such as reduced contrast
PCA	1. Fast Processing Time & high Special Quality. 2. It removes redundancy present in image	1. Spectral Degradation & Colour Distortion 2. Lesser fusion quality than any of the input images
HIS	1. It is Simple ,Efficient & Fast	1. Results in colour Distortion

	Processing 2. It is mainly used for sharpening	2. It only processes three multispectral bands and results in colour distortion
Laplasian Pyramid	1. Offers good Visual Quality 2. Suppressing any noise in the source imagery	All pyramid Decomposition Based Fusion methods produce more or less similar output. The number of decomposition levels affects image fusion result
Integer Lifting Wavelet Transform	1. Provides good result at level 2 decomposition 2. This is best technique over all DWT, DCT, PCA, MAX/MIN techniques. It gives high quality fused image and takes less computation time	1. It is Time consuming 2. In many cases like multilevel decomposition it can produce little complexity
DWT	1. Better Signal to Noise ratio 2. Different rules are applied for decomposition on low and high portions of signal	1. Less Spatial Resolution 2. It is not possible to fuse images at different sizes
DCT	1. Beneficial in Real Time Applications 2. It takes less time for computation as compared to DWT	1. Quality of fused image is not up to the mark 2. Fusion quality of this method is not good as DWT