A HYBRID IMAGE FUSION APPROACH BASED ON DCT AND PCA

A Dissertation submitted towards the partial fulfilment of
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Submitted by

SHALVY RANA

Roll No. 2K11/SPD/22

Under the esteemed guidance of

SH. RAJESH BIROK

(Associate Professor)

Department of Electronics & Communication Engineering
Delhi Technological University
(Formerly Delhi College of Engineering)
Delhi-110042
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SHAHBAD DAULATPUR, BAWANA ROAD, DELHI-110042

CERTIFICATE

This is to certify that the dissertation title "A **Hybrid Image Fusion Approach based on DCT and PCA**" submitted by **Shalvy Rana, Roll. No. 2K11/SPD/22**, in partial fulfillment for the award of degree of Master of Technology in "**Signal Processing and Digital Design (SPDD)",** run by Department of Electronics & Communication Engineering in Delhi Technological University, is a bonafide record of student's own work carried out by him under my supervision and guidance. To the best of my belief and knowledge the matter embodied in dissertation has not been submitted for the award of any other degree or certificate in this or any other university or institute.

Sh. RAJESH BIROK

Supervisor

Associate Professor (ECE)

Delhi Technological University

Delhi-110042

DECLARATION BY STUDENT

Date: ___________

I hereby declare that the work presented in this dissertation entitled **"A Hybrid Image Fusion Approach based on DCT and PCA"** has been carried out by me under the guidance of **Sh. Rajesh Birok**, Associate Professor, Department of Electronics & Communication Engineering, Delhi Technological University, Delhi and hereby submitted for the partial fulfillment for the award of degree of Master of Technology in Signal Processing & Digital Design at Electronics & Communication Department, Delhi Technological University, Delhi.

I further undertake that the work embodied in this major project has not been submitted for the award of any other degree elsewhere.

Shalvy Rana

2K11/SPD/22

M.Tech (SPDD)

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Shalvy Rana

2K11/SPD/22

M.Tech (SPDD)

ABSTRACT

This thesis work, presents **A Hybrid Image Fusion Approach based on DCT and PCA**. In this, a multisensory image fusion scheme based on the Directional DCT combined with PCA has been implemented and assessed. The source image were divided in to non overlap square blocks of equal size and fusion was carried out in the respective blcoks. This approach works in two levels where in the first level, mode 0 - 8 were executed on the source images. The coefficient from the input images are utilised in the fusion procedure, for every mode. Similarly, procedure is continued for remaining mode as well. The fusion procedure is carried out using the 3 diverse fusion rules i.e., 1. Averaging of respective coefficient (DDCTav), 2. Selecting respective frequency bands with the maximum energy (DDCTek) and the 3. Selecting respective coefficients having maximum absolute values (DDCTmx) among the images. Later, in the next level, we get 8 different fused images which are generated one from every mode. The second level begins with fusion of these eight generated images by PCA. The fused output image obtained from PCA is further enhanced by passing through an averaging filter which gives the final fused output image. Performance of the algorithm were compared using fusion quality evaluation metrics such as RMSE, PSNR, S.D., Entropy, etc. It was concluded that though the overall performance of the algorithm is mediocre when compared to other traditional fusion schemes, but enhanced output showed improvements in the implementation resuts in terms of the performance metrics.

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CHAPTER 1
INTRODUCTION

1.1 Outline

The definition of Image fusion are the process of mixing different image from multisensory or multimodal sources with complementary data content to generate a superior image with enhanced image properties and all significant details of the source images.Current fast implementations in the criteria of imaging techniques, multi-sensory a reality in related are RF (Automatic and manual) sensing, medical imaging, embedded system, DSP and the military security requirement behalf. Image fusion delivers an efficient way of decreasing the increase area of data content by extracting the useful data content from source images and other noisy image. It provides an efficient method to allow comparison and the analysis of Multi-sensor data having invert data content about concerned criteria and detection. The outputs is new image that is more efficient for the goal of human/machine perception, and for further digital image-processing tasks such as color segmentation, Classification object detection or target recognition in applications such as RF (Automatic and manual) sensing and MRI, CT-SCAN imaging with feature extracting.

Images from different large sensors typically have totally different pixel behalf geometric showing that ought to be reworked to a standard illustration for fused. This illustration ought to retain the most effective color saturation of either device. The alignment of different large pictures is additionally one among the foremost require for fundament step. Different large is additionally stricken variations within device pictures. However, image fusion doesn't essentially imply large sensors sources. There is one -sensors or large sensors fused that has been vividly represented during research work.

The method of different sorts image data content fusion, image object fusion is sometimes performed at a amongst the 3 totally contrast process steps: **pixel, feature and decision**. picture element step image fusion, additionally called signal-level, show fusion at very cheap level, mid level wherever variety of square measure combine to supply one amalgamate image signal and better economical image. Feature level may be a middle level of fusion that extract vital options from a picture like form, length, edges, segments and direction with color properties of image. Finally, the very best level, call info fined by native call manufacturers operational on the results of show parameter level process on image knowledge made from per region and camera feature of image. Figure 1.1 shows system victimization image fusion in any respect 3 levels of process this square measure most significant of image process.

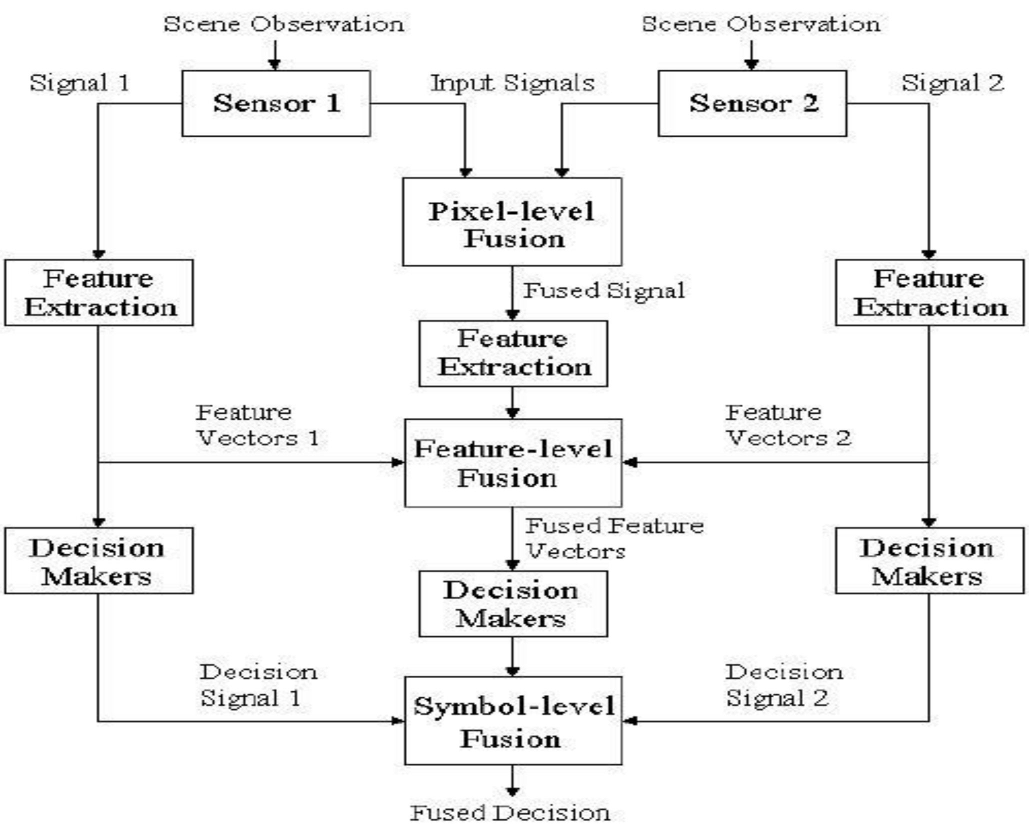

Fig. 1.1 Fundaments information content fusion system at all three image processing levels.

These methods can be mostly classified by two that is **spatial domain fusion** and **transform domain fusion**. Averaging, Brovey method, Principal Component Analysis (PCA), related methods are spatial domain methods and these methods are finding image parameter. But spatial domain methods generate lowest noise less in the fused image (output image).This problem occur now be solved by a transform (like as DWT, DCT etc) domain approach. The DCT based method is better for fusion and image quality enhancement with the help of image filters. The discrete wavelet transform has also become a very important for fusion with 2D image compression. The images used in image fusion should already be registered first as shows in figure.

1.2 Research Motivation

The analysis is essentially owing to the fields of multi-spectral, high resolution, sturdy and value effective image capture device style methodology with Diamond State noising of 2 completely different pictures. Since previous few decades, with the foremost introduction of those multi-sensory imaging methodology, image fusion has been associate degree growing field of current analysis in RF based mostly sensing, medical imaging, visual modality, military security and civilian aeronautics, autonomous vehicle navigation, recognition technique, feature extraction, hid weapons detection, varied security and police work systems applications. There has been lots of improvement in dedicated real time imaging systems with the high abstraction, spectral resolution also as quicker digital image process technology system. The answer for knowledge content overloading is met by a corresponding increase within the range of process units, victimization quicker Digital Signal process (DSP) and bigger memory storage devices like as RAM and store. This methodology but, is quite high-priced and simply style. Pixel-level image fusion methodology represents associate degree higher answer in this drawback of operator connected knowledge content overload and higher PSNR improvement. picture element Level fusion effectively decrease the few quantity that must be processed with none important loss of helpful data content and conjointly merge image from multi-spectral sensors and alternative noise image generating supply. Specific inspiration for the analysis work has come from the necessity to develop some competent image fusion methodology beside the sweetening of lie of fusion technologies and quality sweetening. Exploitation the DCT based Multi device analysis techniques and adding economical image filter technique like as basic MATLAB intrinsically image filter perform, it's achievable to accomplish noise less fusion that finally ends up in associate degree extremely reduced loss of input data like as two all completely different pictures. The planned hybrid fusion ways that throughout this analysis work to boot exhibit improvement and wise image resolution with reference to objective any as quantity analysis purpose of regard compared to variety of these image fusion techniques.

1.3 Image Fusion System by Single Sensor

The fundamental fusion has been showing in Figure 1.2. The detector displayed completely different band may be a visible-band sensors or some quantity of matched band sensors. This detector captivates the current world technique as a image knowledge set of various pictures. The sequence of pictures square measure then amalgamated each to form a brand new image with optimum knowledge content image object and knowledge. as an example in illumination variant and creaking surroundings nature, an individual's operator might not be ready to detected objects criteria of his interest which might be highlighted within the outcome last amalgamated image.

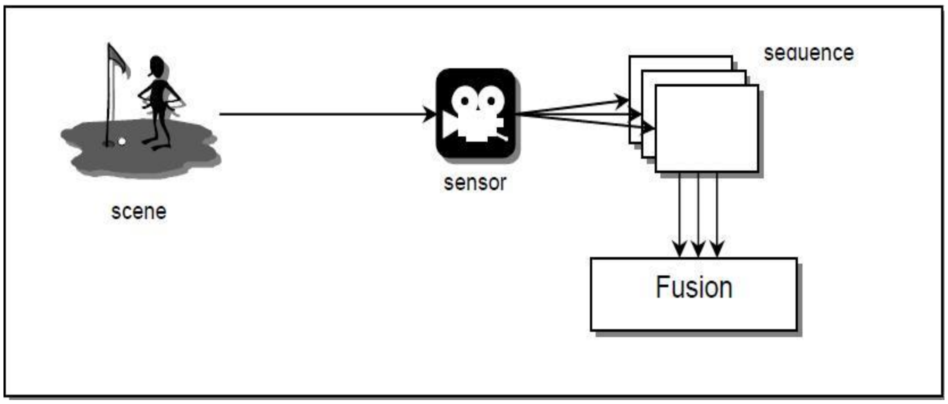

Fig. 1.2 Single Sensor Image Fusion System with its Architecture.

Limitations of this type of systems lies background image behind the shortcomings of the imaging detector that is being used. The conditions, on that the system will work, dynamic vary, resolution, Image parameters, etc., square measure ignoring by the flexibility of the detector. for example, a visible-band detector just like the camera is appropriate for the next gently region surroundings like daylight scenes, but is not appropriate for poorly lit condition found throughout the night (lower light-weight image), or in adverse conditions like in fog or rain.

1.4 Image Fusion System by Multi-Sensor

An image fusion multi-sensor theme takes away the constraints of single detector image fusion by mix the pictures from multi-sensors to form a united image. Figure 1.3 shows a multi-sensor image fusion mechanism. Here, associate degree IR camera is attendant with camera and their explicit pictures square measure united to induce a consolidated amalgamated image. This method removes the issues noted previous. The photographic equipment for daylight scenes; the digital IR camera is suitable in poorly lighted environmental conditions.

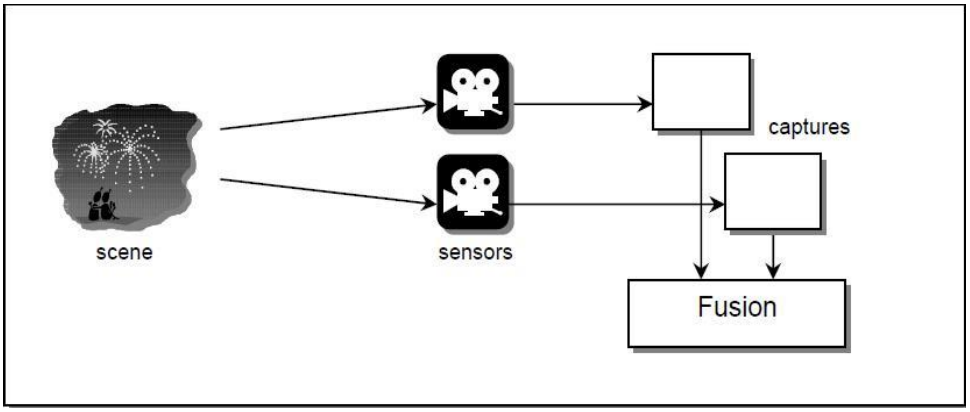

Fig.1.3 Multisensory block representation of Image Fusion System

Blessings of multi-sensor image fusion square measure follow some points:

i. **Increase of reliability** – The conception of fusion of the multiple parameter finding technique will decrease noise and thence, improve the dependableness of measure.

ii. **Sturdy system functioning** – Redundancy in measuring will facilitate within the systems strength. Just in case of 1 or additional detector failure or if the performance of a particular detector mathematical by-product, the system will rely on different basic different sensors and fusion strategies.

iii. **Reduced representation of information** – Fusion ends up in compact showing and higher performance. As an example, in IR sensing, instead of storing imagination from various spectral bands, it's comparatively more practical to store amalgamated knowledge content and knowledge.

iv. **Improved range of operation** – massive sensors that operate below numerous operative condition is accustomed improved sensible vary of operations. as an example, various sensors is used for the day and night operations classes with the opposite environmental conditions.

v. **Improved spatial and temporal coverage** – mix knowledge content from detector that fluctuates in abstraction saturation region will increased abstraction coverage. an equivalent is correct for dimensions etc.

vi. **Reduced irregularities** – mix knowledge content from multiple sensors will decrease the irregularity related to sensing or call method.

1.5 Image Pre-processing

Image pre-processing is an introductory part to enhancement of the image properties from unwanted external noise content interference and controlling, sensors 3D motion, systems noise, etc. This pre-processing contains primary terms and re sampling of the multi-sensor images as explained below:

1.5.1 Image Registration

Firstly, the default images are in different image 2D coordinate system. The image registration method spatially line to line them by one in all the images as a reference and reworking the images one at same time. Hence, a range of related structure or parts within the average image and in every other image is important so as to find a suitable transformation techniques. Once the registration method is resulted, the images are often working for data abstraction.

1.5.2 Image Resampling

Image re sampling is employed to design a brand new image of the image with a different pixel dimensions to get the related data content Re sampling is incredibly important as a result of, the motional imaging is completed on a set time intervals, whereas the ultimate output generation depends on the image being at regular spatial intervals at a time. Hence, there's a requirement to shift the first samples of the image or interpolate between the input values to get the image samples at the output image locations. Re-sampling is employed for the dimensions of an image so as to match the same characteristics of multi-detector image.

1.6 Traditional Image Fusion Techniques

Image Fusion procedures, important data content from each source images is fused both to form a resulting image whose quality is better than any of the input image. Image fusion algorithms, can be broadly categories into following, i.e.,

- Spatial domain in fusion methods
- Transform domain in fusion methods

Basically we tend to image parameter value of the image. The constituent celebrated to realize default output. In frequency domain strategies the constituent worth is 1st delivered strategies by DFT primarily based fusion strategies and additional image is increased by fixing image parameter element of a picture with restricted size of image constituent. Image Fusion work in each field wherever pictures are needed to be analyzed of image. As an example, medical image analysis, microscopic imaging, analysis of pictures from satellite, visual perception, remote sensing application, Machine learning, computer vision and battlefield observation.

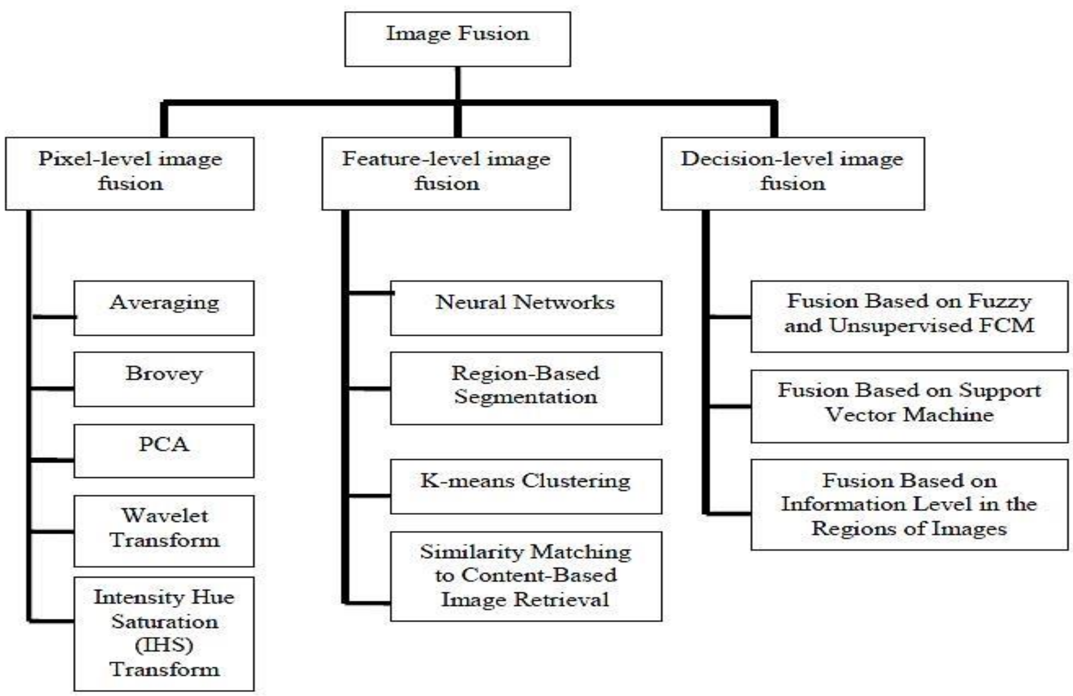

Fig 1.4: Figure showing the classification of Image Fusion techniques

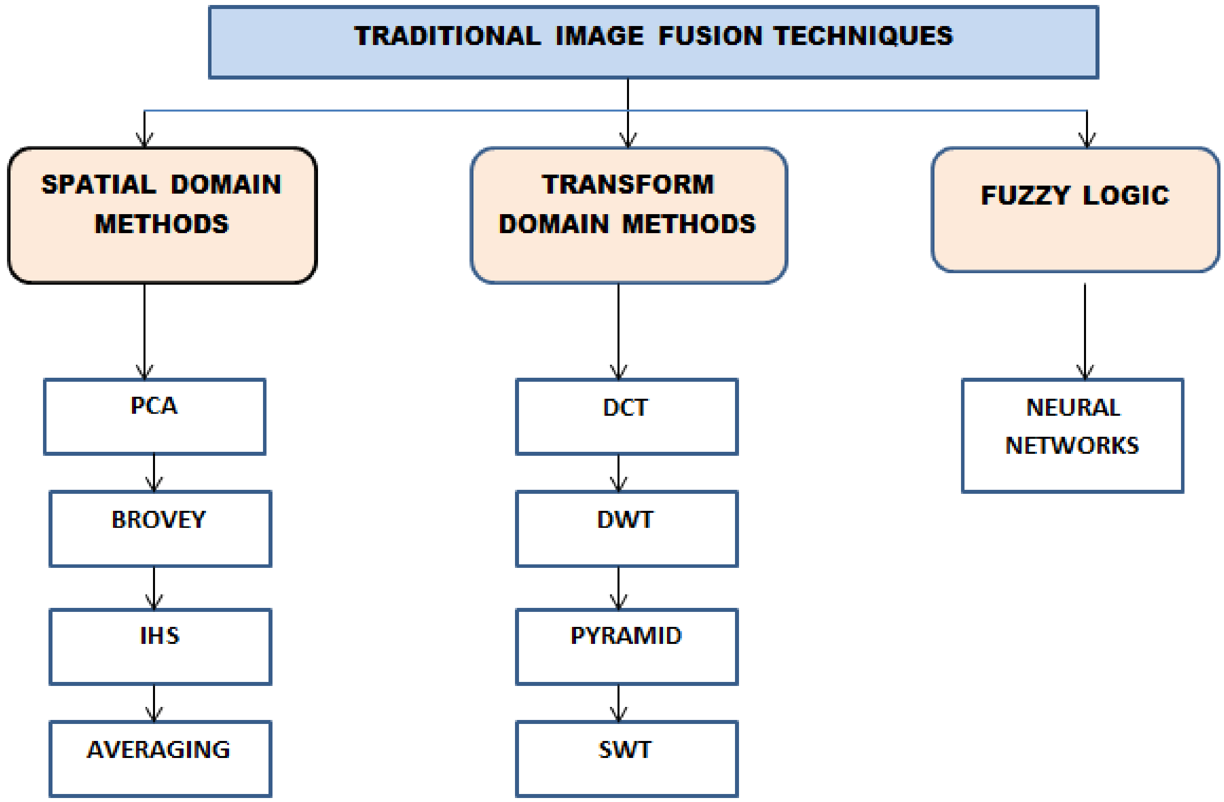

Fig 1.5: Figure showing classification of Traditional Fusion techniques

1.6.1 Spatial Domain Fusion Methods

These categories of fusion are directly used on the applied images which reduce the energy-to-noise ratio of the final fused images with simple averaging method.

1.6.1.1 Averaging Method

Average Method work as averaging every corresponding pixel of input images to obtain final output fused image [3]. It is define mathematical as:

$$F(x,y) = P(x,y) + Q(x,y) / 2$$

Where, F(x, y) is the final fused image, P(x, y) and Q(x, y) are two input images functions [3].This technique is valid only for some essayer applications since one of the input image will always be with very lower lighting/brightness and thus the quality of a resultant averaged image will obviously low with higher Quality. Averaging method doesn't basically offer very better results as it reduces the contrast of the resultant fused image and PSNR.

1.6.1.2 IHS (Intensity Hue Saturation) Fusion Method

IHS transformation is one in the foremost vital strategies employed in a lot of application particularly in IR Controlling applications. IHS vastly represents the recognition of sensory activity color domain and overcomes the limitation of ordinarily used RGB color house that doesn't combined intuitively to the small part of human color perception and image color penetration. [5].Intensity may be outlined as total quantity of sunshine that reaches the attention saturation. It effectively separates spatial (intensity) and spectral (hue, saturation and view) info from a picture.

1.6.1.3 Principal Component Analysis Method

Principal component Analysis (PCA) could be a mathematical tool that (DWT, DCT, HYBRID) variety of correlate variables into variety of unrelated variables and parameters. The PCA remodel converts internally related Multispectral (MS) bands into a replacement set of unrelated elements and effective views. To perform this approach the principal elements of the MS image bands shall be on the market in image. Then, the primary principal element that contains the foremost info of the image is substituted by different image like as un fused image. Finally, the inverse principal element remodel is performed to induce the new RGB (hue, Saturation and View) bands of multi-spectral image from the principle parameter of image process.

1.6.1.4 Brovey Method

These techniques are Image color primarily based traditional rework as a result of it relates a red-green-blue (RGB) color image rework technique. The Brovey transformation technique was developed to get rid of disadvantage of the increasing technique in image fusion. it's an easy technique for connection of information from totally different sensors. During this technique combination of basic addition and subtraction computation associated with bands are normalized before they're increased with the panchromatic different image. It conjointly preserves the corresponding spectral options of every the element and converts all the physical property information content into a panchromatic image of upper resolution and higher capability of image fusion [9].Generates a abstraction noise less 2 totally different coalesced pictures.

1.6.2 Transform Domain Fusion Methods

In transform domain fusion first off the input pictures are rotten supported transform coefficient like as a0, a1--an. Then the fusion technique is applied and therefore the fusion call map is obtained and notice image object. Inverse transformation thereon calls map turn out coalesced image. Rework domain fusion allows the image's salient options are a lot of clearly visible than in spacial domain fusion with different options and parameters. Normally used rework domain fusion techniques are made public as follows some points:

1.6.2.1 DCT (Discrete circular function Transform)

In this methodology, pictures that area unit amalgamate, first of all non mix block having size NxN. Computed for every block and fusion rules area unit applied to induce amalgamate DCT coefficients for specific image size. On the amalgamate coefficients to supply the amalgamate like as N*N.

1.6.2.2 Pyramid Transform

A pyramid structure is outlined as a group of pictures that area unit captured at totally different scales area unit combined every, representing the various original image [2]. a picture will be depicted as a pyramid basic structure once analyzed by use of pyramid rework. Pyramid rework will be performed that during this chapter three ways that.

Laplacian Pyramid

Laplacian Pyramid comes from the Gaussian Pyramid (GP), that could be a multi-scale illustration obtained by playacting algorithmic with unvarying analysis reduction. Recording uses a "pattern selective" and "Sequence Generative" based mostly methodology to fuse the input pictures so as to induce a feature at a time rather than element at a same time [20].

The basic plan of Laplacian Pyramid rework is the start then integrates incorporated 2 pictures of this decomposition to supply a mix composite depiction. Then the amalgamate image is reconstructed by playacting associate degree inverse pyramid rework. The fusion is then enforced for every level of the pyramid exploitation feature choice call algorithms. It will be used many modes of combination like averaging or choice of image process.

Morphological Pyramid

The input pictures captured clanging at totally different scales, at any level L is formed by applying morphological filtering with a 3×3 structuring part to the image level (L-1) followed by down-sampling (by an element of 2) the filtered and combined image.

Gradient Pyramid

The fusion procedure in Gradient Pyramid is comparable to Laplacian Pyramid methodology. supported the Gaussian pyramid decomposition, it uses four gradient operators so as to create a filtering while not constant quantity within the horizontal, vertical, and 2 diagonal two Dimension. By this fashion, the extracted edge information content of the supply image are higher with the characteristic details. The amalgamate image features a higher definition and contains adequate effective hidden information.

1.6.2.3 DWT (Discrete wave Transform)

In distinct wave rework filters area unit especially implementation in order that serial layer of pyramid solely contains details that area unit while not obtainable. 2D-DWT generates four footage as output that having size that's capable [*fr1] original basic image. Therefore from initial input image we'll get HHa, HLa, LHa, LLa footage and from second input image we'll get HHb, HLb, LHb, Bachelor of Laws footage level. Means that low-pass filter is applied on x and followed by high pass filter on y image dimension. The LL image contains the approximation coefficients with image parameter. Image contains the horizontal detail coefficients. Image contains the vertical detail coefficients and horizontal dimension. The wave retread could also be performed for multiple levels. Resulting level of decomposition is performed victimization exclusively the LL image and various levels. The result is four sub-images each of size capable zero.5 the LL image size.

1.6.2.4 SWT (Stationary wave Transform)

Stationary wave rework (SWT) is analogous to distinct wave rework (DWT) however the sole method of meaning and irregular image parameters properties. The second Stationary wave rework relies on the thought of no devastation. Each down sampling in forward rework and up sampling in inverse rework and opposite transformation methodology. a lot of specifically, it applies the rework at every purpose and so uses the domain knowledge at every level [7].

1.7 Hybrid Image Fusion Techniques

Traditional image fusion methodology lacks the power to induce high-quality image once to mix 2 completely different pictures. So, there's a foul got to use hybrid fusion techniques to realize this objective target archive. The fundamental plan of the hybrid techniques is to mix spatial domain with rework domain fusion techniques to enhance the performance and increase united image quality with reduction of image noise part .Another chance is applying 2 stage transformations techniques on input pictures before fusion method. These transformations give higher characterization of input pictures, higher handling of recurved shapes, and better quality for united details. The blessings of the hybrid techniques area unit up the visual quality and image entropy increase of the pictures, and decreasing image artifacts and noise. Flow diagram portrayal a hybrid image fusion technique of PCA with DWT is shown below for given content:-

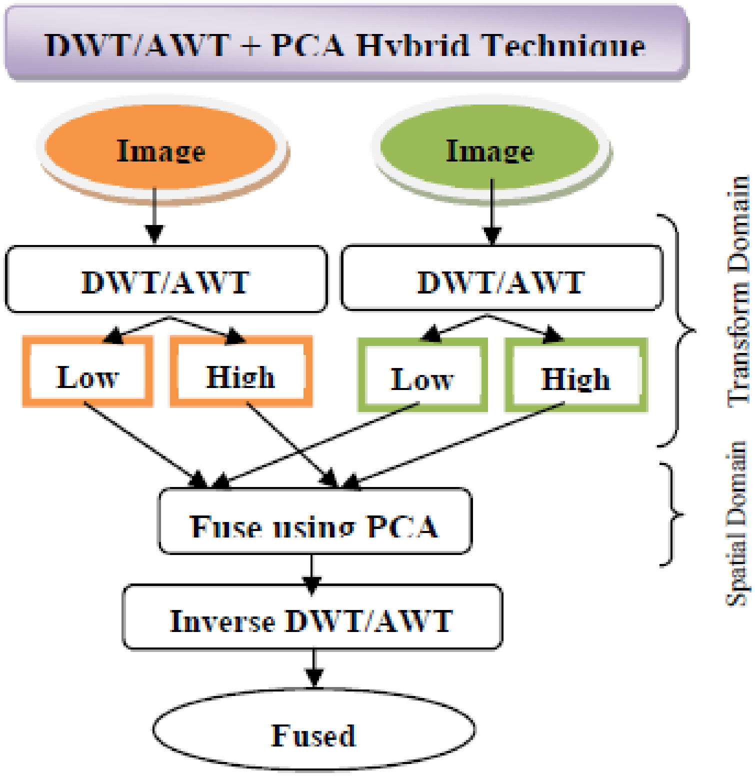

Fig1.6: Figure showing a hybrid image fusion algorithm (DWT + PCA).

1.8 Image Fusion Applications

Image Fusion has become a wide used technique to enhance the visual interpretation of the image in many applications like increased vision system, seeing, diagnosing, feature extraction, robotics, military and police investigation, etc. it's been normally utilized in several fields like object identification, classification detection.

Object identification: to maximize the number content or data being extracted from satellite image data, helpful product are found within the amalgamate pictures.

Change detection: modification detection is that the method of characteristic variations within the state of Associate in Nursing object by observant it at totally different times with same time length. it's a very important method in observation and managing natural resources and concrete development as a result of it provides mathematical measuring of the higher distribution of the population of interest. Image fusion for modification detection takes advantage of the various configurations of the platforms carrying the sensors and image fusion.

Remote sensing (RS) applications ar involved with the acquisition of geo-spatial pictures mistreatment aerial photography by satellites and wireless communication primarily based captured image and mobile sensors, like SPOT, Quick Bird, IKONOS and federal agency. RS aims to deliver top quality geographic pictures in terms of each abstraction and spectral resolutions for functions like urban designing, agriculture and earth science and geographical location.

Ocean police investigation for detection, tracking, go and identification of any craft or ship or the other object to be monitored for security functions and microwave radar, SONAR primarily based multi application or for rescue operations, etc.

Defense/Security applications vary from air-to-air or surface to defense and war attacked condition, field of battle intelligence, police investigation and target acquisition and strategic warnings and application. They aim at detection, pursuit and identification of enemy aircrafts, ground targets.

Environmental monitoring targets at locating or identification of natural climate phenomenons.

1.9 Thesis Outline

The remainder part of this thesis is divided some in the following chapters:

Chapter 2: Literature Review

This chapter illustrates the written account evolution of some competitive image fusion algorithms from numerous papers each within the fields of Image fusion techniques analysis of recent Articles.

Chapter 3: Image Fusion Techniques with Proposed Methodology

This chapter discusses about the traditional and hybrid image fusion techniques in detail with fundamental approach. Also, detailed description about the proposed fusion algorithm based on Directional DCT with PCA followed by a 2D filter to get the enhanced output result is given using block diagrams and formulations and mathematical calculation.

Chapter 4: Implementation results and Discussion

This chapter presents the implementation of the image fusion algorithms along with the results and comparisons. The software requirements, the dataset used and the quality metrics used for the work have been mentioned for in this chapter. The result screenshots and analysis is provided in detail for each dataset and values for performance metrics are presented in tables as now to shows.

Chapter 5: Conclusion and Future Scope

This chapter presents the overall conclusion of the thesis Investigations and calculations.

References: This section gives the reference details of the thesis. And reassert papers.

CHAPTER 2

LITERATURE REVIEW

For the past few years, an extensive research has been done in order to develop techniques aiming at fusion of visual images. These procedures differ in complexity, strength and sophistication. Few of the principle works of the widely used image fusion methods are discussed below:

Patil, U et al.[4] presents an algorithm for image fusion based on hierarchical PCA. In this, author defines that the image fusion procedure involves mixing of preregistered images of a similar scene to generate a superior image including all the significant details of the source images. Hierarchical image processing technique for multiscale and multiresolution images, pyramid decomposition is the prime idea for most fusion algorithms. A commonly used fusion scheme is Principal component analysis (PCA). The image fusion scheme proposed was a hybrid methodology based on PCA and pyramid technique where the qualitative analysis of the output image was done without using reference image.-

Katartzis et al.[7] presented the idea with SR remodeling supplying the outline of commonly used representation techniques in domain. The overall idea of characterizing super resolution contains 3 critical procedure stages which include low-resolution acquisition of image, image registration and high-resolution image remodeling. The authors proposed a novel fusion technique using the Normalised Convolution method. The quantitative and qualitative metrics were analysed on the real-time video datasets.-

Mitianoudis et *al.* [8]showed the effectiveness of Independent Component Analysis(ICA) & topographical Independent Component Analysis(ICA) methods based transforms which were mostly used for the image fusion process. Offline training by means of comparable scenes images is imparted to the bases. A new pixel based rule is used for fusion of images in the transform domain. A un-supervised adaptation ICA based method is also introduced for fusion.

The comparative analysis between the wavelet, transform based methods and proposed methodology shows superior performance and slightly improved computational complexity by the latter. The author suggested that the bases make much effective tool and can complement the commo methods for image fusion such as the Dual Tree Wavelet Transforms. Correct directional sensitivity, precision in capturing key features of an image are some of the offerings of topographical ICA based techniques.-

Li and Yang [9] introduced a region based image fusion approach in the spatial domain utilizing fixed-size blocks. Implementation results show that despite the rawness of used segmentation techniques, the proposed fusion algorithm outcomes are outstanding in terms of the visual perception. The proposed region based scheme is pretty easy computationa wise and can find its application in the real world. Though, the outcomes are encouraging but a lot of factors need to be taken into account when matched to MR based methods. Therefore, a lot of research is necessary to develop adaptive schemes for selecting those factors.-

Desale, R.P et al [3]explained about the PCA(Principal Component Analysis), DWT(Discrete Wavelet Transform) and DCT(Discrete Cosine Transformations) based fusion schemes, their formulations and their process flow charts. Their implementations outcomes are tabulated for efficient performance analysis and comparison of the mentioned schemes. The results implies that some predictable fusion approaches like PCA and DCT have a lot of disadvantages over DWT, which seems advantageous considering their improved fusion results. They also proposed two DWT based techniques for fusion namely Maximum pixel replacement and pixel averaging.-

Prakash, C et al. [5] talked about the medical image fusion and its applications in the inventive disease diagnosis. Several multimodal practices in medical image fusion and their evaluated results are shown with their performance metric calculators. Redundancy Discrete Wavelet Transform(RDWT) and Madani type minimum-sum-mean of maximum(MIN-SUM-MOM) based fusion approaches are applied on the pre-registered source images i.e.,CT & MRI whose resulting images are evaluated using the several performance metrics namely OCE, PSNR, SNR, SSI, MI, etc. Finally, they concluded from the resulting outcomes that the MIN-SUM-MOM method is superior to RDWT in terms of performance and productivity.-

Hall, David L.[10] et al. explained about the multi sensor data fusion and its benefits over single sensor data fusion like precision in finding the correct location of object and observability.
They also discussed the inevitability the multi sensor fusion has in the defence applications as well as in other fields. According to them, multi sensor data fusion depends highly on the co-registration process, which is actually a type of placement of two or more images overlapped in such a way that all the images represent the same scene.

Firouz Abdullah et al informed that HIS is among the commonly used fusion approaches and discussed about the various HIS based methods to transmit an image from RGB to HIS space. The resulting outcomes from these approaches is used to evaluate their performance using some of the available quantitative metrics like the Standarad Deviation, Normalisation Root Mean Square Error, PSNR, Entropy, Correlation Coefficient, etc. It is concluded in the research that the fusion approaches based on HIS transform display vivid results which is dependent on the used formulation.

Yee leung, Jmnminliu et al. explained in their research that the commonly used HIS schemes work on replacing the Panchromatic images with the intensity of component bands, because of which, the bandwidth of Panchromatic images does'nt overlay correctly with the MS band spectral response. In order to overcome the issue, the intensity adaptation is very necessary. Therefore, an Adaptive Intensity Hue Saturation(AIHS) scheme is applied where a suitable weighting matrix determines the total amount of spatial information injected into the bands of MS images.

Chavez Jr., P S et al explained PCA is actually a substitute for HIS approach for image fusion.
Panchromatic images are replaced with the first principle component, that is, pc1 in PCA approach. As pc1 has much larger mean and variance values than the Panchromatic images, so prior to any replacement, it gets necessary for the Panchromatic images to be histogram

equalized to pc1. The results suggested that PCA showed less spectral distortion in fused band when compared to HIS, though it cant be evaded fully.

Nisha Gawari et al. discussed the various image fusion schemes based on PCA, DWT and DCT algorithms, their process flow charts and the formulations. In PCA, the authors used mathematical projections in order to condense the image to fewer principal components or variables whereas DWT and DCT see the transformation of images from spatial to frequency domain and then the fusion execution on the transform coefficients. Lastly, as the fused outcomes are gained by carrying out their inverse transform their performance analysis concluded that DWT is far more superior in performance than the PCA and DCT based approaches.

Wencheng Wang proposed a competent Laplacian pyramid based fusion method which primarily consisted of 3 stages. To start off, the laplacian pyramid are created for all the input images, then these pyramid levels are combined by implementing the various fusion methods. While the max. region information method is implemented for the topmost level, the max. region energy method is apopted for the rest. Lastly, the inverse of the laplacian pyramid is applied to get the final fused image.

VPS Naidu [12] presented the 6 types of DCT(Discret Cosine Transform) based image fusion schemes, which are namely DCT e, DCT cm, DCT ah, DCT ma, DCT ch, and DCT av and did their performance analysis. He noted that the fusion results were affected badly when the block size was less than 8x8. The results suggested that out of all the methods presented, the performance of DCT mx and DCT e was better than the rest and were far more suited for real time applications.

VPS Naidu [14] introduced, developed and executed the five different block DCT based fusion algorithms namely Feature DCT (FDCT), Wavelet Structute DCT (WSDCT), Sub-band DCT(SDCT), Morphlogical DCT (MpDCT) and Re-sizing DCT(RDCT). The results were analysed and it was concluded that out of the five WSDCT based fusion performed the best.

Hui Li et al. implemented the algorithm based on wavelet fusion where the area based max. selection fusion approach followed by a consistency verification map is executed after the input images are decomposed. Lastly, inverse of the wavelet transformation is done to obtain the fused result. It is noted from the study this scheme can be utilized to fuse two or more multisensor images and is best suited for Optical to SAR and visible to infra-red fusion.

Shaoqing Yang et al. presented an scheme utilizing HIS and DWT for the purpose of color image fusion. This approach works on averaging of the wavelet coefficients for the input images. The results/ outcomes are obtained and analysed and can be applied successfully to fuse color image from various Electro optical trackers.

Joshing and Chao, reported that to decompose the input images, the wavelet packet based approach is utilized. A new fusion scheme was introduced based on the frequency domains(high and low). The low frequency parts are calculated manually for which the threshold and weight are applied while the high frequency fragments using the high-pass filtering image fusion method.

Kanaka Raju Penmetsa et al. presented a color image denoising approach based on DT-CWT. He says that basically CDWT is type of DWT only where by applying a dual tree of wavelet transformation, the complex coefficients are produced. The algorithm was executed on color images and the implementation results are approximated to evaluate the performance of the scheme. It is concluded that in terms of visual eminence, the DT-CWT is a superior scheme.

Heba M. El-Hoseny, et al. [2] investigates some of medical image fusion techniques in their work and discusses the most important advantages and disadvantages of these techniques to develop hybrid techniques that enhance the fused image quality. Both conventional and hybrid fusion techniques are assessed using numerous quality metrics such as avg. gradient, S.D., local contrast, structure similarity index, entropy, universal image quality index, feature similarity index , PSNR, mutual info., Qab/f, and processing time. Implementation results prove that the hybrid method of Additive Wavelet Transformation(AWT) and DualTree complex wavlet transformation (DT-CWT) with high pass sharpening filter provides the best fused images of highest quality, highest details, shortest processing time, and best visualization. This is favorable, especially for helping in accurate diagnosis and optimal therapy applications.

P. Gomathi et al. studied and proposed an algorithm based on Non Sub-sample Contourlet Transformation for multi-modal medical fusion. This algorithm decomposes the input source images to low-pass and high-pass subbands using the NSCT, then fusion is applied on these subbands by means of mean variance based fusion methods. By applying the Inverse Non sub-sample Contourlet Transform(INSCT) to fused subbands. 6 datasets of the medical images are used for implementation and the respective results are evauated using some performance metrics like S.D., entropy, mean, Qab/ F. Obtained results evaluation conclude that the presented fusion method shows superior results than pre-existing fusion schemes.

Tian, Yu et al. The author proposes a novel method utilising an improved pulse coupld neural network (IPCNN) in the non sub-sampled contourlet transformation (NSCT) domain. First of all, the input images are decomposed into sub bands with different scale and direction by NSP and NSDFB. Next, local area singular value is introduced to determine the structural information factor which will be the linking strength parameter of PCNN. After the fire process we can get the fire mapping images that can reflect the characteristics of single pixel and its neighborhood. Then, we extract the objects with salient features of the fire mapping images by compare-selection operator. Finally, deconstruct the fused image by inverse NSCT. Our proposed algorithm in multimodal medical image fusion is proved to perform better in robustness and reliability over the existing methods, meeting the requirement of human vision.

T.Zaveri, M et al. [6]studied and discussed regarding a region based image fusion algorithm and showed how these approaches outperform the pixel based fusion schemes. Here, large amount of pre registered images are used to implement the discussed approach and the usual reference and without reference based metrics are used to evaluate the outcomes.

Yi. Chai presented a fusion method based on the focussed regions detection and multiresolution which follows the following steps: At first, the lifting stationary wavelet transform(LSWT) is used to acquire the first fused image. Now, the morphlogical opening and closing similarity measures are used and the border pixel are choosen from the first fused image in order to choose the focussed region. Finally, the fused image is obtained by combining these focussed regions, thus reducing the issue of data loss in the multiscale transformation based methods. Though LSWT exhibits numerous benefits such as the reduced no. of distortions, reduced complexity, shift invariance, reliability and loss of contrast data, etc ,but also has limitation where the incorrect outcomes sometimes appear at the focussed region's boundaries.

In 2015, the author [17] proposed a multifocus & multi sensor image fusion algorithm based on the Dense scale invariant features transform (SIFT). 3 terms namely spatial consistency, local contrast and the exposure qualities are used for every source image, this signifies how efficient is the dense Scale invariant features transform (SIFT). This technique was accepted to eliminate the ghosting artefacts encountered when the cqptured scene contains mobile things. This methodology is used to increase the fused image quality and is the best to work with when comparing the mis registered pixel in the multi source images.

In 2016 Yu Liu [19] implemented the signal decomposition scheme for image fusion based on convolutiounal sparse representation (CSR). CSR technique could get over the shortcomings of the sparce representation procedures, that is, the skill in detail conservation and great sensititvity for mis-regitration.CSR based fusion background was used for the proposed scheme designing where the input images were disintegrated into the detail as well as the base layer. This method was found to be superior than other sparse representation techniques.

In 2017 Dogra et al. [16] proposed an image fusion method based on the HIS wavelet transformation domain. This cascaded algorithm for the image improvement and fusion of osseous and the vascular and are able to maintain a high data transmission rate. This method makes it necessary for improving the input image before performing the fusion.[143]. The results are also great.

CHAPTER 3

IMAGE FUSION TECHNIQUES WITH PROPOSED METHODOLOGY

Image fusion is the most upgrowing field for medical diagnosis or remote sensing and many other fields that merges the essential features from different source images into a single one with extended information content and reduced redundant data and artifacts that may exist in the source images [1].Traditional Image fusion processes may be implemented in the spatial or the transformation domains. Spatial domain fusion techniques include simple averaging, simple maximum fusion, PCA, and Intensity Hue Saturation (IHS). These techniques have some advantages and disadvantages [2]. Simple averaging fusion technique is the simplest algorithm, but it does not introduce clear objects from the image datasets. Simple maximum fusion produces greatly focused images, but blurring is the main disadvantage that affects the local contrast, greatly. PCA fusion produces spectral degradation, and IHS is not appropriate for medical image fusion as it mainly deals with color images [3]. Transform domain fusion techniques include DCT, DWT, DT-CWT, Pyramidal, curvelet transform, etc. All transform domain techniques convert images into multi-resolution or multi-scale image representations before fusion, and then apply inverse transforms to obtain the fused images [4]. Despite the good performance of transform domain fusion techniques, they still have some disadvantages. DWT fusion poorly handles long curved edges, has poor directionality, is shift sensitive, destroys phase information, and provides less spatial resolution. Curvelet fusion is more efficient in handling curved shapes, but more complex and consumes longer time. DT-CWT can increase directionality, achieve better edge representation, and has an approximate shift invariance property compared to DWT [4-5].

For efficient utilization of image fusion techniques, multi-level fusion algorithms can be designed to accomplish good spatial resolution and quality spectral content. In this work, both the traditional and the hybrid medical image fusion techniques are investigated for the purpose of obtaining the best fused image quality.

3.1 Principal Component Analysis

This Principal Component Analysis (PCA) technique is spatial domain approach widely used for Image fusion. It is especially used for image compression and image classification processes. PCA is commonly utilized to decrease the multi dimensional data set to lesser dimensions for the investigation purpose or it’s a vector space that transforms the interrelated variables in to theuncorrelated ones namely the principal components. The main benefit of PCA is the minimal information loss in the fused image when their data size is compacted and dimensionality transformed. Weighted averages need to taken of the source/ input images in order for image fusion to occur.Eigen vectors related to the biggest of the Eigen value of the covariance matrix for each of the sources images are utilised to find the weights for each of them. It calculates a compress and a great description of data set. The PCA basis vectors like FFT, wavelet and DCT are varying rapidly and basis vectors depends on the dataset. The direction of maximum variance is used to calculate the first principal component. The 2^{nd} principal components, is required to be located into the sub space vertical of the very first principal component. Maximum Variance direction is pointed by this component in the sub space. 3^{rd} principal components is in the direction of maximum variance in the Sub space vertical to first 2 components, so on. PCA is termed as hotelling transformation or Karhunen- Loeve transformation too. A block diagram showing a PCA based fusion mechanism is drawn in Fig. 3.1. Source images I1 (x, y) and I2 (x, y) are the 2 column vector and there respective empirical mean are subtracted from each other. The resultant vector have measurement of nx2, where the n is the length of each of the images vector. Calculate eigen vectors & eigen values for the resultant vectors are evaluated and eigen vectors matching the higher eigen value are acquired. Normalised component P1 & P2 (that is., P1 + P2 = 1) are calculated from acquired eigen vectors.

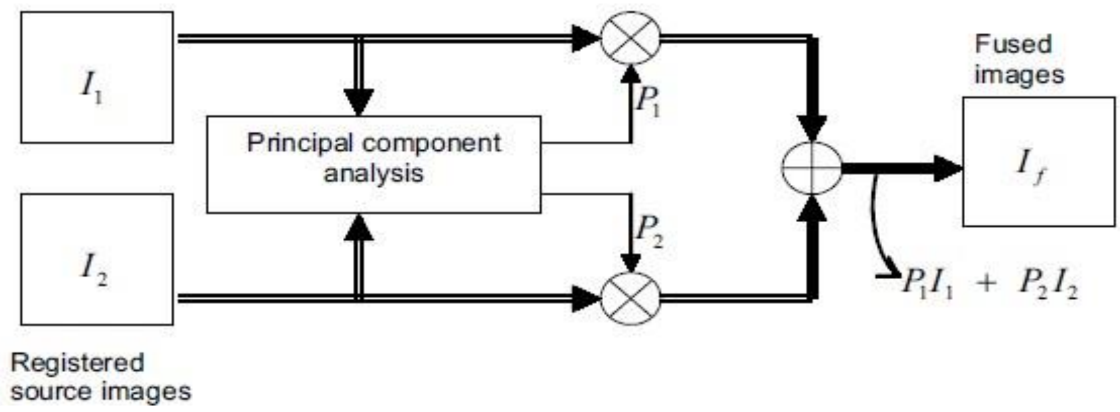

Fig 3.1: Block Diagram of Image Fusion by PCA

PCA Fusion is carried out in the following steps:

a) In order to ensure similar size source images , the size check is performed for the input images.

b) After that, the source image are organized in to the column vector. Let Z be the resultant column vectors with the measurement Nx2.

c) Alongside each of the column, the empirical mean is computed. The dimensions of the Empirical means vector denoted by Ev is 1x2.

d) In the matrix Z, Ev is deducted from each column. Dimensions of the resultant matrix X are 2xN.

e) Finding the co-variance matrix C from the matrix X.

f) Now, calculate eigen vector & eigen value of matrix C and then arranging them in the reducing pattern eigen value.

g) Considering the 1^{st} vector column which also corresponds the largest Eigenvalue in order to calculate the normalised components P1 & P2.

Fused output images are denoted by :

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

,in which the P1 & P2 are normalised component such as $P_1 = V(1)/\Sigma V$ and $P_2 = V(2)/\Sigma V$ in which V be the eigen vector then the $P_1 + P_2 = 1$.

These techniques like PCA transform, HIS, and the Brovey Transformation are producing great image but are also encountering some disadvantages. Biggest among them is the issue of colour distortions.

3.2 Discrete Wavelet Transforms

Discrete Wavelet Transform is a transform domain technique for image fusion which offers a time and frequency illustration of signals. Initially, it was created to get over the limitations of

The Short-Time Fourier Transforms (STFT)s, though they can also find their use in investigating the nonstationary signal. Although the STFT usually provides with constant resolution for every frequency level, the Wavelet Transformation utilises multiresolution procedure through which various frequencies can be examined and that too with diverse purposes.

The wavelet transformation provides with a multiresolution decomposition of an image in the biorthogonal basis whose results are displayed in to nonredundant image demonstration. Wavelet is the name given to that basis and mother wavelet is a single function on which if we perform the transformation and dilations, the wavelet functions are created. Figure 3.2 illustrates a discrete wavelet transform flow diagram. In the demonstrated filter bank, firstly, we take two input signals and then pass them through respective 1-D filters i.e., H0 and H1, where H0 executes the high pass filtering while the other one H1 does the low pass filtering. The filters are usually followed by sampling operation where down sampling by a factor of 2 is performed. In the second stage, the signals are is remodeled by performing up-sampling first, followed by filters F0 and F1 respectively and finally adding the subbands.

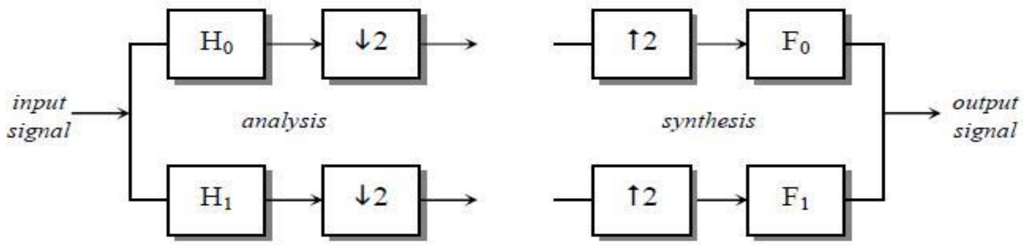

Fig. 3.2: Two channel wavelet filter banks

DWT in Image Fusion

Effective fusion methodologies are required for the image to be perfectly placed pixel by pixel basis. Here, the image that needs to be fused together are are expected to pre-register first. Two source images image 1 and image 2 are the input signals. Wavelet transformation performs the image decomposition in to the 4 frequency band which are, low_low, low_high, high_low, high_high. Implementing the wavelet transformation on the input image produces their wavelet coefficient. Now, by applying the average of the inputs, fusion of input image wavelet coefficients is carried out. Finally, the inverse wavelet transformation is executed to acquire the final resultanat fused image.

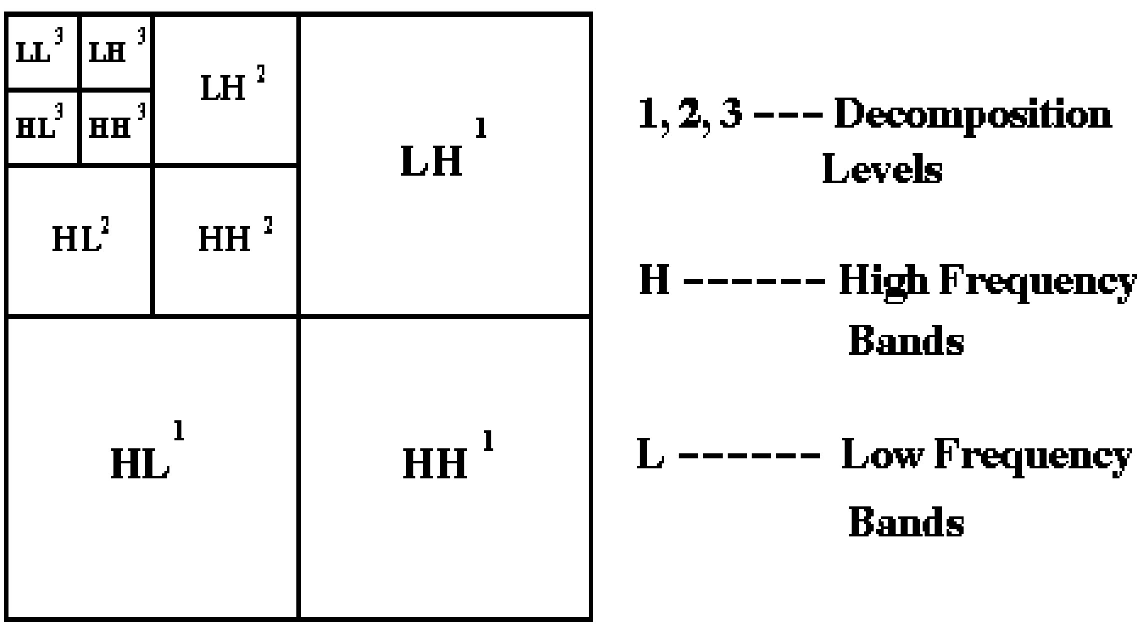

Fig3.3: Composition and Decomposition of DWT

DWT are commonly faced by several applications related to the image & video compressions, bio-informatics, pattern recognition, etc. Because of their unbelievable merits, 2D DWT is implemented for the planning of fusion. Final outcomes acquired from 2D DWT with the 9/7 filter show clearer output images with large PSNR values.

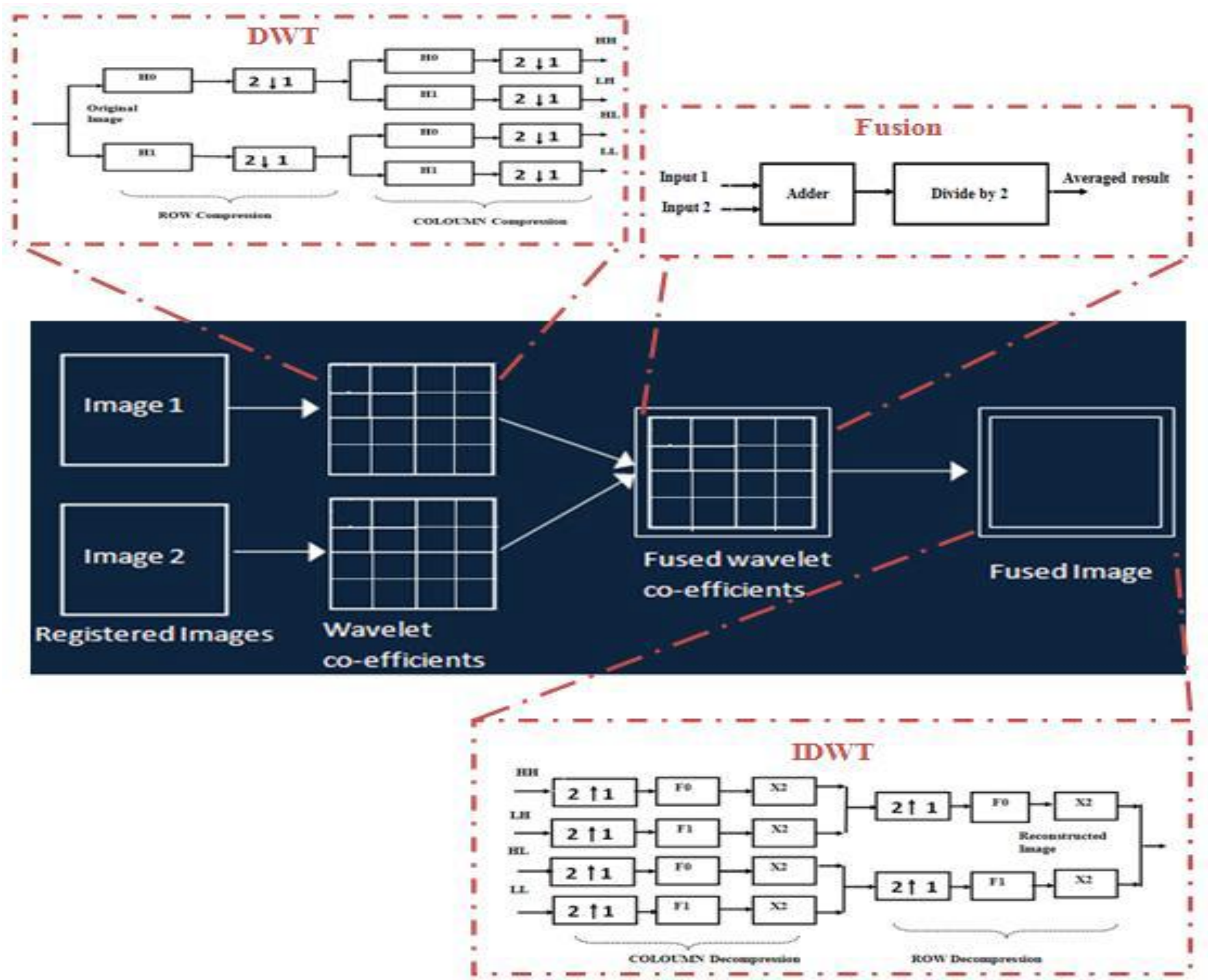

Fig 3.4: Flow Diagram of DWT based Image Fusion

The registered images are transmitted as the in put signal from 2 diverse 1-D filters denoted by H0 & H1 separately. The H0 & H1 filters implement the highpass and the lowpass filtering operation correspondingly for all in put image. The filter outputs are followed by the down sampling operation, that too by a factor of 2. This operation is named as Row compresssion and the respective results are termed the L- low frequency component and H- high frequency component. Output signal obtained from the down-sampling operation, are transmitted further to the 2 1-D filters, to accomplish Column compressions.

The frequency component achieved at the out put after 2 level of decompositiin of both source image are as follow: **H_H** High-High, **H_L** High-Low, **L_H L**ow-High, **L_L** Low-Low. In figure 3.4 a block flow diagram of the image fusion approach based on DWT that contains 2 source image, the DWT blockk then the fusion block, finally the I-DWT block. The frequency components of the 1^{st} source images i.e., H_H, H_L, L_H and L_L are combined with component of the 2^{nd} source i.e., H_H, H_L, L_H and L_L correspondingly. Now, H_H component of the 2 source image are then added together and resulting outcome is divided by the factor of 2. Likewise, average of the H_L, L_L & L_H component are calculated. The procedure is called Images Fusion where this average outcome is later followed by the remodeling procedure which is the inverse of the wavelet transformation.

DWT based block calculates the 2 sets of the coefficients/variables which are namely the approximation coefficient and the details coefficienta. Those vector are acquired by performing the convolution of in put value with lowpass filters for the calculation and also with highpass filters to get the details and the outcome in to the gathering of the subbands having lesser bandwidths and a sluggish sampling rate. When each filter length is equivalent to the 2N where, n = the length of input signal, then length of out put signal got from filter is n + 2N − 1, also lowpass & highpass coefficient is with length [{(n-1)/2}+N]. 2-stage of the DWT disintegration yields the 4 subbands H_H, H_L, L_H and L_L. Subbands from all image are fused together doing the combining of the H H coefficients of 1^{st} input with the H H coefficients from the 2nd. Likewise, in the rest of the coefficient H L is combined with the H L, L H is combined with the L H and then L L is also combined with the L L. This fusion is broadly executed in the 2 stages:

Stage 1: coefficient from the image are summed then
Stage 2: summed outcomes are then divided by 2.

The outcome obtained from the Fusion block is feeded as the input to the I-DWT block. I-DWT is utilised for calculating inverse of the discrete wavelet transformation(I-DWT) and rebuilding the signals obtained from subband with a fewer bandwidth and slow sampling rate. Once the inverse of the wavelet transformation of the input is calculated in the block, the output dimensions are same as of input image. Every columns outcome is I-DWT off respective in put columns. While recreating the signals, block utilises sequence of the highpass & lowpass filter in order to remodel signals from in put subband. The remodelled signals have greater band width and quicker sampling rates whenever compared with in put subband.

3.3 Discrete Cosine Transformation

Here, we would like to discuss the **Discrete Cosine Transform** (**DCT**), which displays limited series of the data point w.r.t. the sum of the cos function fluctuating at the dissimilar frequencies. DCT is crucial for several fields of application like in the science & technology fields, starting from the loss compressions of an image & audio (in which the minor high frequency where small high frequency parts are rejected), ranging to the spectral approaches for the numericals solution of PDE(partial differential equations). Usage of cos instead of the sin function are crucial for the compressions, as it is known that lesser no. of cos function are required in order toa estimate a signal, whereas for the differential equation cosine expresses a specific selection of the boundry condition.

To be precise, the DCT is like Discrete Fourier transform (DFT), which is Fourier related transformation, however it only uses the real number. DCT is usually linked with the Fourierr Series coefficient of the intermittently and proportionally stretched series while DFT is linked with the Fourier Series coefficients from periodically extended series. DCT is equal to the DFT with approximately double of the length dimension, fuctioning on the real information with uniform symmetry, whereas in other variants the in put and/or out put data is moved by margin of half of the sample.

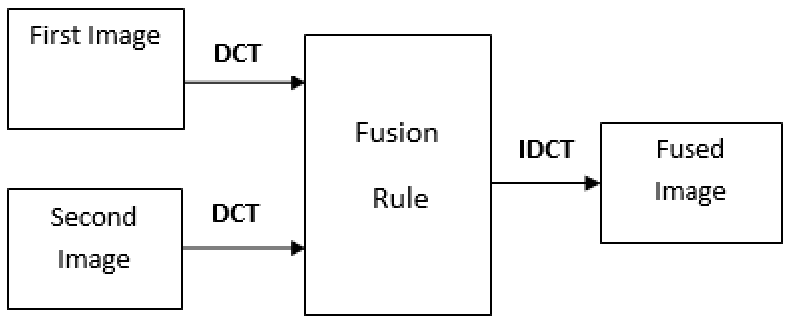

Fig 3.5: Block Diagram of DCT based Image Fusion

DCT is among the critical transformation found in the image processing domain. As the lower frequencies are populated with the large no. of the DCT coefficient, therefore, the DCTs are recognized for their outstanding energy compression property. Let 1-D DCT be X(k) for the series x(n) with length of N can be denoted as follows-

$$X(k) = \alpha(k)\sum_{n=0}^{N-1} x(n)\cos\left(\frac{\pi(2n+1)k}{2N}\right), \quad 0 \le k \le N-1 \qquad (1)$$

$$\text{where} \quad \alpha(k) = \begin{cases} \sqrt{\dfrac{1}{N}} & k = 0 \\ \sqrt{\dfrac{2}{N}} & k \neq 0 \end{cases} \qquad (2)$$

One can see that for k=0, the Eqn. (1) becomes

$$X(0) = \sqrt{\frac{1}{N}}\sum_{n=0}^{N-1} x(n)$$

The first transformation coefficients are the average for entire sample of the series, they are called the DC coefficients, while the other transformation coefficient are called the AC coefficient.

Now, IDCT , that is, inverse of the discrete cosine transforms are denoted by:

$$x(n) = \sum_{k=0}^{N-1} \alpha(k) X(k) \cos\left(\frac{\pi(2n+1)k}{2N}\right), \quad 0 \le n \le N-1 \qquad (3)$$

Eqn. 1 are usually known as the analysis formulae or the forward transformation while Eqn. 3 are termed as the synthesis formulae or the inverse transform. The basic series is-

$$\cos\left(\frac{\pi(2n+1)k}{2N}\right)$$

The 2D DCTs are the straight extensions of the 1D DCTs. Here, 2 Dimensional DCT of the images or a 2-D signal i.e., x(n1,n2) of the size of N1,N2 is said to be X(k1,k2), this can be mathematically denoted by:

$$X(k_1,k_2) = \alpha(k_1)\alpha(k_2) \sum_{n_1=0}^{N_1-1} \sum_{n_2=0}^{N_2-1} x(n_1,n_2) \cos\left(\frac{\pi(2n_1+1)k_1}{2N_1}\right) \cos\left(\frac{\pi(2n_2+1)k_2}{2N_2}\right), \quad \begin{array}{l} 0 \le k_1 \le N_1 - 1 \\ 0 \le k_2 \le N_2 - 1 \end{array} \qquad (4)$$

where 1 a(k) n 2 a(k) both are comparable to Eqn (2).

Likewise, the 2-D I-DCT is shown by:

$$x(n_1,n_2) = \sum_{k_1=0}^{N_1-1} \sum_{k_2=0}^{N_2-1} \alpha(k_1)\alpha(k_2) X(k_1,k_2) \cos\left(\frac{\pi(2n_1+1)k_1}{2N_1}\right) \cos\left(\frac{\pi(2n_2+1)k_2}{2N_2}\right), \quad \begin{array}{l} 0 \le n_1 \le N_1 - 1 \\ 0 \le n_2 \le N_2 - 1 \end{array} \qquad (5)$$

The DCT and the I DCT both are separate transforms and they get a huge benefit because of this property which is that the 2-D DCT and/or 2-D I-DCT can also be calculated in a 2 stages i.e., consecutive 1-D DCT and/or 1-D I-DCT operation onto the column then over the row of the images x(n1,n2) as displayed in the Fig. 3.6.

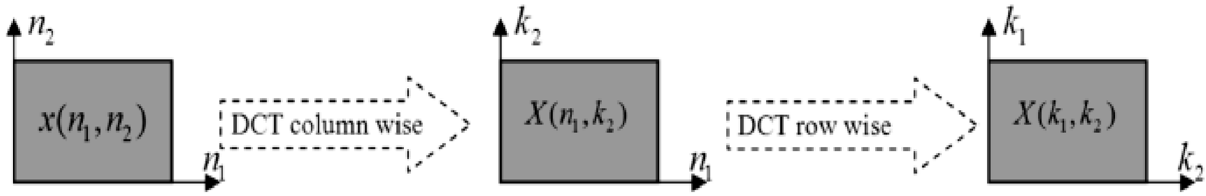

Fig 3.6: Calculation of 2-D DCT using separability property

3.4 PROPOSED HYBRID FUSION METHODOLOGY

The technique of multisensory image fusion is a scheme which integrates a multitude of pre-registered image in to resultant composite image which is more appropriate in purpose of the visual perceptions. Fused output consists of perfect explanation of the scenes better than the input images. Lately, MSIF has transformed into the subject of intensive study and improvement. The input image might have been acquired from same sensor or multiple sensors. Input image must be pre-registered. MSIF has found applications in innumerable fields like military surveillance, remote sensing, medical diagnosis, intelligent robots, computer vison, microscope imaging, defect inspection, flights vision systems, artillery detection, etc. The image fusions occur at the various stages of data demonstration, which are the signals level, pixel level, feature level & the symbolic level. The fusion at pixel level can be performed by joining the input images with out any pre-processing. Furthermore, techniques of MSIF are notable on the condition that whether the fusion of image was implemented in spatial or the transformation domains.

The requests which need enforcement on fusion outcomes are mentioned below:

1). The resultant fused outcome must save all the significant details of the source image in the fusion process.

2). The process must be free from artifacts and irregularities.

3). The fusion procedure must be free from any dependency in the shift, the scale and any rotation.

Normally, 2-D DCT are implemented on the non overlapping images divided in to blocks of the square of size(N×N). 2-D DCT(conventional) is executed separateley by 2 N point DCTs, one in horizontal and the other in vertical directions. In relation to the HVS(human visual system), both the directions are crucial. 2-D DCTs delivers finest outputs of the images block in which the horizontal as well as verticel edge are controlling. Edge of other directions apart from horizontal & vertical are also critical and their edges orientation changes hugely from one block to other. Due to this, in order to evade the nonzero AC component in frequency domains, the directional DCT (DDCT) is a great option over the conventional DCTs. DDCT where, 1st DCT is implemented over the governing directions with in image blocks, whereas 2nd Npoint DCTs could be implemented in line with organization of coefficients after 1st N point DCTs. Lately, Directional DCT has been commonly utilized in the codings for the images and the videos. PCA is the mathematical algorithm which changes the no. of interrelated variable in to the no. of uncorrelated ones known as the principal component. The principal components are the ones which are responsible for all the variance in data as much as possible. The 1st principal component is usually obtained in direction of maximum variance. 2nd components are restricted to fall in the sub space which is perpendicular to the first and it indicates towards direction of max. variance from inside the subspace. 3rd components are acquired in direction of maximum variance in sub space perpendicular to 1st and 2nd and then so on. [1]

In our thesis work, an images fusion method which is a hybrid of the Directional DCT & PCA methodology is proposed. This method is executed in 2 stages. The 1st step looks at the source image being pass through the 8 mode of the Directional DCT method. We get the 8 resultant fused images(one from each mode)and then in 2nd step, we combine the 8 resultant fused images utilizing the PCA method. Fused outcome are then passed through an image filter in order to filter out any extra noise or artifacts. The final result is single fuse image which consists combined data from the two input image. Success of this algorithm is assessed by comparing the fusion qualitative metric like the root mean square error (RMSE), spatial frequency (SF), Peak Signal to noise ratio(PSNR), Standard Deviation and Entropy.

3.4.1 Directional DCT

Let the 1-D DCT X (k) be the transform of series x (n) which is of the length dimension N is denoted by:

$$X(k) = \alpha(k)\sum_{n=0}^{N-1} x(n)\cos\left(\frac{\pi(2n+1)k}{2N}\right), \quad 0 \le k \le N-1 \tag{1}$$

where

$$\alpha(k) = \begin{cases} \sqrt{\frac{1}{N}} & k = 0 \\ \sqrt{\frac{2}{N}} & k \neq 0 \end{cases} \tag{2}$$

The first transformation coefficients X (0) be the avg. of the entire sample in series and are identified as the DC coefficient, while the other transformation coefficient are named the AC coefficient {X(k),k=1,2,…,N−1}.

Inverse of DCT are denoted by:

$$x(n) = \sum_{k=0}^{N-1} \alpha(k) X(k)\cos\left(\frac{\pi(2n+1)k}{2N}\right), \quad 0 \le n \le N-1 \tag{3}$$

Eqn.(1) is usually known as the analysis formulae or the forward transformation and the Eqn. 3 are termed the synthesise formula and/or the inverse transformation. The DCT and the I DCT are discrete transforms and benefit of the property is 2-D DCT and 2-D I-DCT could be evaluated in the 2 stages where consecutive 1-D DCT and 1-D I-DCT operation on the column and later on the rows off the images x(n1,n2).

There are a total of 8 direction mode(from mode 0–1 and to mode 3–8) for a random size dimension N×N. The mode 0 & 1 is like the traditional 2-D DCTs. The modes 3(which is diagonal down-left) and the modes 5(which is vertical-right) are most important mode. The other mode can be easy derivative of the mode 3 & 5 by performing transposing or reversing on them.

The Mode 3 (diagonal down-left mode)

Assume a N×N block of the image which is depicted in the Fig.3.7(a). 1-D DCT is executed along the down-left direction diagonally for all the diagonal lines(illustrated using dot lines) with the n1 + n2 = m, m = 0,1,…,2N−2. Looking at Fig 3.7 (a), as we know, actually their is 2N-1 times the diagonal down-left 1-D DCTs need to be implemented, their length dimensions are denoted by Nm=[1,2,…,N−1,N,N−1,…,2,1], and the coefficient is alligned into the columns vector as presented in the Fig.3.7(b). 1st row in the Fig.3.7(b) consists of DC component followd by the AC component. Secondly, 1-D DCTs are executed horizontally (which is row wise like as displayed by the drawn arrow lines in the Fig.3.7(b)), the coefficient is then pushed towards horizontally left the same way as displayed in Fig. 3.7(c) and are defined by:

$$[X(k_1, k_2)]_{k_2=0:2N-2-2k_1} \ \ \& \ \ k_1 = 0,1,\ldots,N-1$$

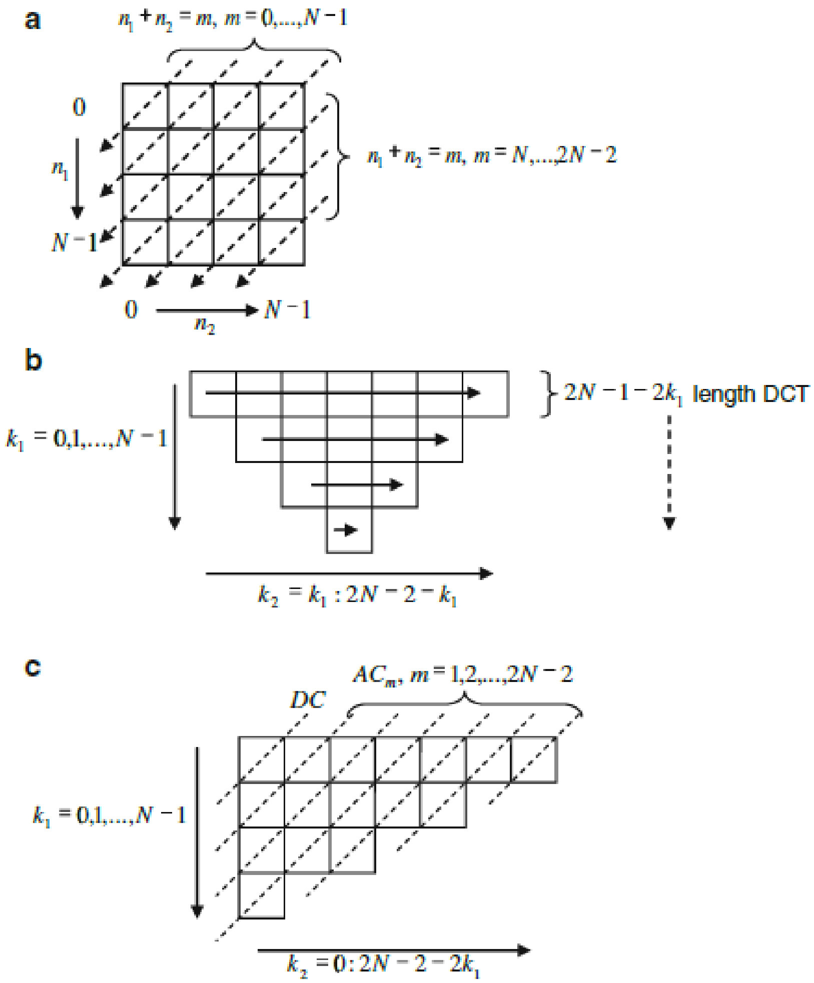

Fig3.7: a)A NxN block of image in which first 1-D DCT is executed in down-left direction diagonally(Mode3) b)Organization of coefficient after the 1st DCT and the 2nd 1-D DCT to be executed horizontally(the *arrow lines)* c) Organization of coefficient after the 2nd 1-D DCT executed in horizontal direction and the DC & AC components(the *dotted lines*)

Mode 5 (Directional DCT for the vertical-down mode)

We considering a N×N block of image as presented in the Fig. 3.8(a). Execute 1-D DCTs in the vertical-right direction(drawn as the dotted arrow) and coefficient as displayed in the Fig. 3.8(b). Based on those coefficient, the 1-D DCTs are executed in the horizontal direction and the coefficient is then pushed towards the left as displayed in the Fig. 3.8(c). The resulting coefficients are defined as:

$[X(k_1,k_2)]_{k_2=0:N \;\; for\; k_1=0,1,\ldots,\frac{N}{2}-1 \;\; \& \; k_2=0:N-2} \;\; for\; k_1=\frac{N}{2},$
$\frac{N}{2}+1,\ldots,N-1$.

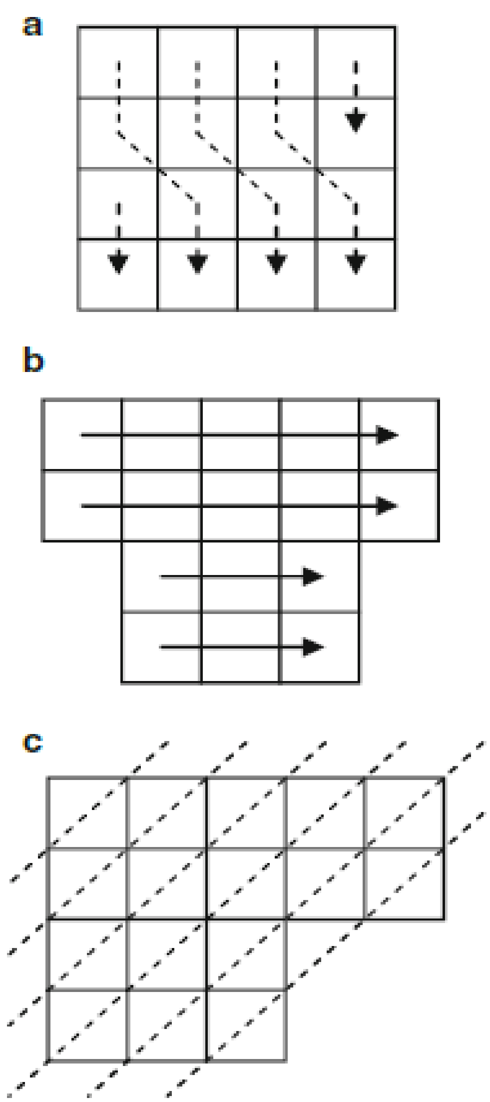

Fig3.8: a) A N×N block of image in which the first 1-D DCT is executed in the vertical-right direction (i.e., mode 5). b) Arrangement of the coefficient after the 1st DCT & the 2nd 1-D DCT to be executed horizontally (drawn as the arrow line). c) Arrangement of the coefficient after the second 1-D DCTs executed in horizontal directions and the AC & DC component (drawn as the dotted line)

As stated before, various mode in the D-DCT and in their respective evaluation procedures is tabulated in the Table 1.

Mode	Direction	Procedure
0	Vertically down	Apply 1D DCT column wise and then apply 1D DCT horizontally (each row)
1	Horizontally right	Transpose the image block, apply mode 0 procedure
3	Diagonally down-left	In Mode 3
4	Diagonally down-right	Flip the image block horizontally and then apply mode 3 procedure
5	Vertical-right	Explained in Mode 5
6	Vertical-right	Transpose the image block, apply mode 5 procedure
7	Vertical-left	Flip the image block horizontally and then apply mode 5 procedure
8	Horizontal-up	Transpose the image block, Flip the block horizontally and then apply mode 5 procedure

Table1 : Table showing different modes inDirectional DCT and their computational procedures

3.4.3 Image Fusion using Proposed Technique

This section discussed the three diverse image fusing rules based on the Directional DCT. The source images are distributed in to nonoverlap block, of the sizes N×N as demonstrated in the Fig. 3.9. The Directional DCT coefficient are calculated for each of the block and the fusion scheme is executed to acquire the fuse D-DCT coefficient. Inverse D-DCT is later implemented to fuse coefficient to yield fused image or block. This process is then continued for every block.

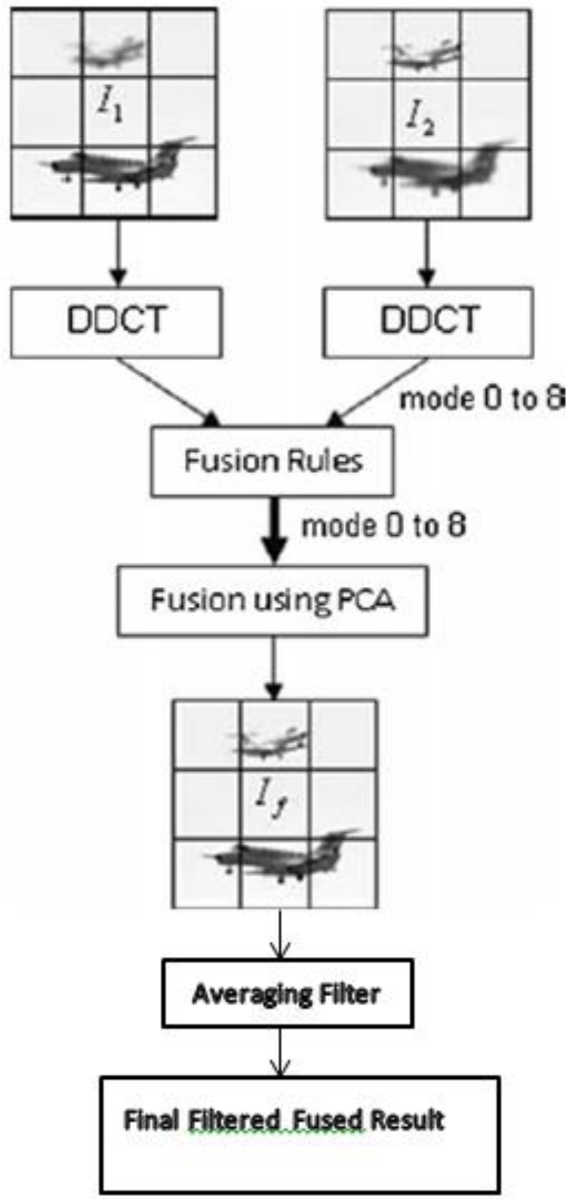

Fig3.9: A model of proposed Directional DCT-PCA based fusion scheme

The following mentioned fusion method are utilized for the images fusion procedure. Assume X_1 is the Directional DCT coefficient of the image blocks in the source I1 and in the same way, assume X_2 to be Directional DCT coefficient of the image block in the image I_2. Consider, image block of the sizes dimension N×N and then X_f is the fused D-DCT coefficient.

DDCTav

Here, the D-DCT coefficient of the input image are utilized to achieve the D-DCT coefficient of the fused images. Weight averages of D-DCT coefficient of the input image are computed, and are allotted to respective D-DCT coefficients bands of the final fuse images. To make it easy, value of weighted graph are used i.e., W_a and the W_b are 0.5 respectively. Then, we take mathematical averages of the D-DCT coefficient for source images. It is denoted by below mentioned equations:

$$X_f(k_1, k_2) = 0.5*(X_1(k_1, k_2) + X_2(k_1, k_2)) \quad (10)$$

Where

k1, k2 = 0, 1, 2,…, N−1

DDCTmx

Here, for D-DCT coefficient of the source images are matched to gain the D-DCT coefficient of final fused image. Highest value of D-DCT coefficient of the input images are computed and allotted to respective D-DCT coefficients bands of the final fuse images. For a nicely focussed object in image, there is need to have the sharp edges and corners detection in band wherever the objects are not in the focus. Hence, by utilising the fundamental approach, we utilise maximum D-DCT value because max. value relate to improved sharper edges and corners detection purposes.

These are denoted with the below equations:-

$$X_f(0,0) = 0.5(X_1(0,0) + X_2(0,0)) \quad (11a)$$

$$X_f(k_1,k_2) = \begin{cases} X_1(k_1,k_2) & |X_1(k_1,k_2)| \geq |X_2(k_1,k_2)| \\ X_2(k_1,k_2) & |X_1(k_1,k_2)| < |X_2(k_1,k_2)| \end{cases} \quad (11b)$$

Where k1, k2 = 1, 2, 3, …N-1

DDCTek

This fusion scheme works on the notion that bands with the maximum energy for their D-DCT coefficient have better and sharp images. It's credited for the fact that, the position of image of actual focus usually has the maximum energy. Therefore, in order to detect the images having sharp images quality, matching of energy coeffiients of D-DCT band is carried out. For the specific bands, max. energy from the input image are evaluated and then allocated to final coefficient of image.

$$X_f(0,0) = 0.5(X_1(0,0) + X_2(0,0)) \qquad (12a)$$

$$X_f(k_1,k_2) = \begin{cases} X_1(k_1,k_2) & E_{j1} \geq E_{j2} \\ X_2(k_1,k_2) & E_{j1} < E_{j2} \end{cases} \qquad (12b)$$

where

k1,k2=1,2,3,…,N−1

j = k1+k2

to compute energy of D-DCT coefficient. Energy of the D-DCT coefficient are denoted with Ej, where Ej, is mean amplitude of jth frequency band and can be defined by:

$$E_j = \frac{\sum_{j=t+p} |X(p,t)|}{Y} \qquad (12c)$$

where

$$Y = \begin{cases} j+1 & j < N \\ 2(N-1)-j+1 & j \geq N \end{cases} \qquad (12d)$$

Image fusion using PCA

Principal component are calculated, PC1 to PC8 using Eq. 9 from the attained eigen vector. Then, the fused image is obtained by:

$I_f = PC_1I_1 + PC_2I_2 + \ldots + PC_8I_8$

Filtering the fused output

The final step in this algorithm, is to pass the fused output image obtained after PCA i.e., I_f through a pre-defined 2-D filter in MATLAB named fspecial(). Here, we create a 2-Dimensional filter of a special type which can be among average, Gaussian, laplacian, etc. It returns back co-relational kernel which is supposed to be the correct form to use with **imfilter().** The imfilter(A, h) filters the multi-dimensional array A with the multi-dimensional filter h.

The output received after applying the filter on the fused image is our final output image. The final output is the single fused image which consists of the significant information from the two input image. Efficiency of this algorithm is computed by matching the performance metrics of the Final outcome with outcomes from other algorithms.

3.5 Fusion Quality Evaluation Metrics

The fusion quality evaluation metric are used in the thesis in order to compute the effectiveness of the image fusion methods used. There are several techniques and measures that can be used in evaluating the fused images. This work discusses and implements the following metrics to the final fused image results [2]:

3.5.1 Root Mean Square Error (RMSE)

The parameter can be calculated as root mean square error of the equivalent pixel in the reference images I_r and the fused images I_f. This metric/parameter becomes approximately zero if reference and the fused image is same. It increases as difference between the images increases.

$$RMSE = \sqrt{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}\left(I_r(i,j) - I_f(i,j)\right)^2}$$

3.5.2 Spatial Frequency

This frequency in the spatial domain shows the complete motion index in fused images and significant equations to evaluate spatial frequency can be computed using Eq. 16c. Spatial frequency calculates the complete information level in the image. Spatial frequency for an image I of the dimensions M×N can be denoted by:

$$\text{Row frequency :} \quad RF = \sqrt{\frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=1}^{N-1}[I(i,j)-I(i,j-1)]^2}$$

$$\text{Column frequency :} \quad CF = \sqrt{\frac{1}{MN}\sum_{j=0}^{N-1}\sum_{i=1}^{M-1}[I(i,j)-I(i-1,j)]^2}$$

$$\text{Spatial frequency :} \quad SF = \sqrt{RF^2 + CF^2}$$

Where

M	no. of rows
N	no. of columns
(i,j)	pixel index
I	given image
I(i,j)	gray value of pixel (i,j)

3.5.3 Peak Signal-to-Noise Ratio (PSNR)

It is quantitative metric based on the Root Mean Square Error(RMSE), and can be evaluated by:

$$PSNR = 10 \times log(\frac{(f_{max})^2}{RMSE^2})$$

In which, the f_{max} denotes maximum pixel gray level of value in remodelled images.

3.5.4 Image Entropy (E)

It is the measure of the total amount of information stored in the image, it takes values from 0 to 8, and can be defined as:

$$E = -\sum_{i=0}^{n} p\ (x_i)\ log\ p(x_i)$$

In which, x_i of the i^{th} point is the grayscale value, and the p is probability. Please note that image seems better, if it has higher entropy value.

3.5.5 Standard Deviation (STD)

This parameter is utilised to determine the amount of variation in image data from its average or the mean value. Image appears to be clearer if it has lasrge STD values. It is calculated by the equation:

$$STD = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|f(i,j)-\mu|^2}{MN}}$$

In which M and N denote the dimension of image f(i,j), and its mean is denoted by u .

CHAPTER-4
IMPLEMENTATION RESULTS AND DISCUSSION

4.1 Implementation Results

In this section of our thesis, the algorithm is performed in three stages. Firstly, the traditional fusion algorithms are applied to the image dataset, then hybrid and finally the enhanced hybrid scheme which are evaluated using the quality metrics mentioned in the previous chapter. Practical work and programs of fusion techniques are designed in MATLAB R2013a using the Image Processing Toolbox on a Windows 10 Laptop powered with an Intel CORE I3 Processor using a 3 GB RAM with a 500 GB Hard Drive space.

The proposed hybrid image fusion methodology based on the directional DCT and PCA followed by a 2-D filter which is used to enhance the fused output, has been developed and implemented using numerous multisensor image in the standard image database. The performance of proposed fusion algorithm is evaluated successfully with multisensor and multi-focus image datasets shown below:

Test Dataset 1

Fig 4.1 : Input Image 1 & Image 2 of Test Dataset 1(Multifocus Images)

Test Dataset 2

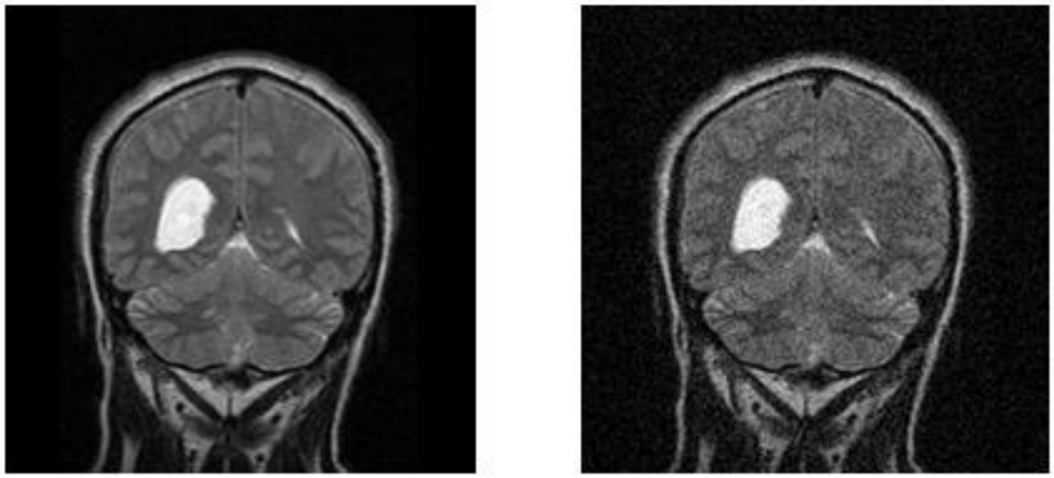

Fig 4.2 Input Image 1 & Image 2 of Test Dataset 2(MRI Images)

Test Dataset 3

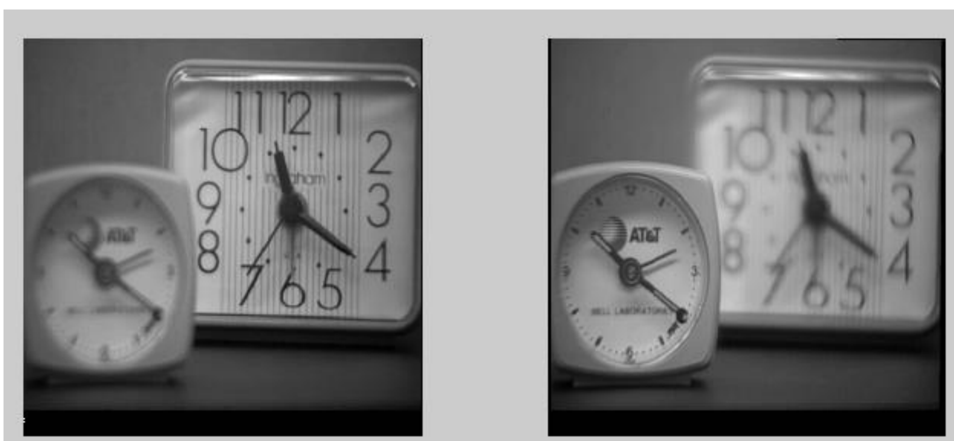

Fig 4.3: Input Image 1 & Image 2 of Test Dataset 3(Multifocus)

In this work, we have taken complimentary source image (data set-1 & 3) in order to assess the fusion methods. The image are complementary in a way that the top airplane is out of focus and lower airplane is in the focus and vice-versa. We get the fusion output results after performing the algorithms on the respective test datasets. The fusion outputs of the respective datasets are displayed below. The first image in Fig.4.4, 4.6 and 4.8 displays fused images and second image displays the error image(difference between the original and the fused image). Finally, we get the filtered output shown in fig after passing the fused image through the Image filter applied in the final step of the algorithm. Please note that the fused output images must contains all the necessary data from the two input images.

Output from Test Dataset 1

Fig4.4: Fig showing fused output image and error image for test dataset-1

Fig4.5: Figure showing final filtered output of test dataset-1

Output from Test Dataset 2

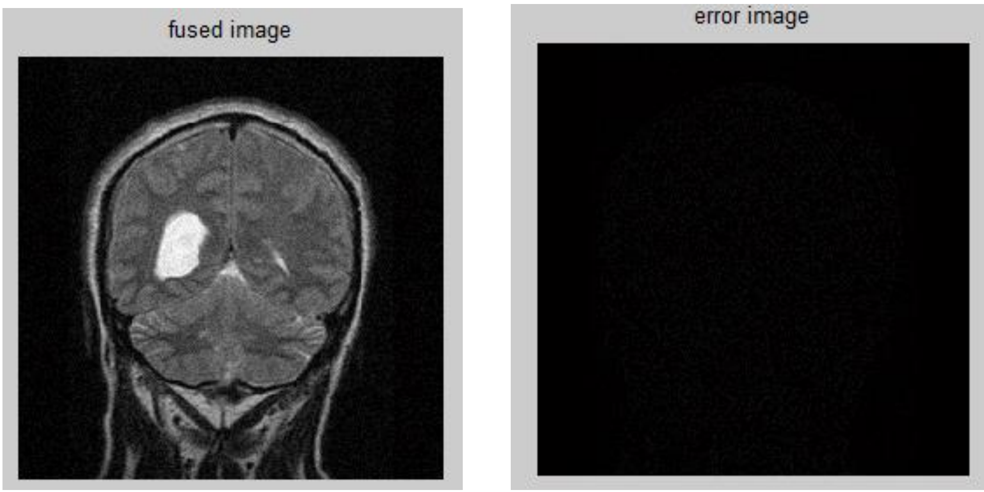

Fig4.6: Fig showing fused output image and error image for test dataset-2

Fig 4.7: Figure showing final filtered output of test dataset-2

Output from Test Dataset 3

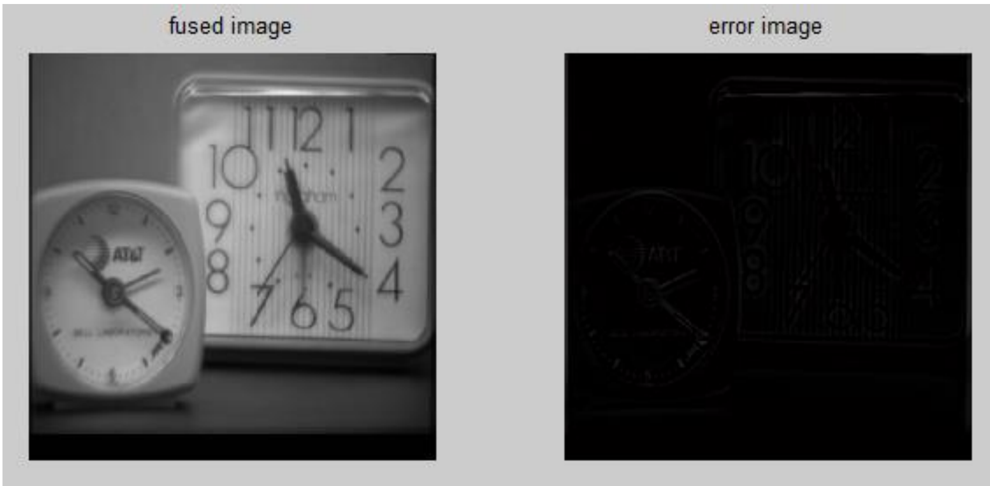

Fig4.8: Fig showing fused output image and error image for test dataset-2

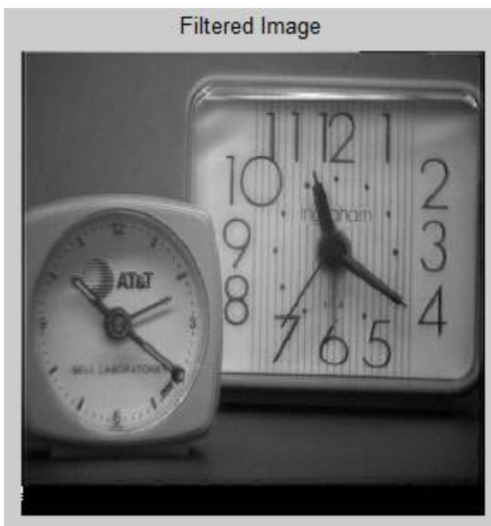

Fig4.9: Figure showing final filtered output of test dataset-3

We introduce here the samples of the calculated results. Table 2,3 & 4 displays the experimental results of the proposed as well as enhanced proposed by using a filter on dataset 1, 2 and 3 respectively.

Test Dataset1	PROPOSED HYBRID(DDCT +PCA)	FILTERED OUTPUT
RMSE	0.0369302	0.0090192
PSNR	62.4569542	68.5790592
ENTROPY	4.0203782	4.1674002
S.D.	0.1799232	0.2116122

Table2 : Table showing results for Test Dataset1

Test Dataset2	PROPOSED HYBRID(DDCT +PCA)	FILTERED OUTPUT
RMSE	0.0310902	0.0156982
PSNR	63.2045872	66.1722932
ENTROPY	6.4667402	5.9552692
S.D.	0.1931052	0.2569302

Table3 : Table showing results for Test Dataset2

Test Dataset3	PROPOSED HYBRID(DDCT +PCA)	FILTERED OUTPUT
RMSE	0.0296042	0.0006842
PSNR	63.4172662	79.7814372
ENTROPY	7.2586932	7.3196532
S.D.	0.1933952	0.1976902

Table4 : Table showing results for Test Dataset3

4.2 Performance Evaluation & Discussion

The quantitative as well as qualitative evaluation of this thesis work using several multisensory image test datasets has been performed and the results are shown in the above respective tables. The performance comparison of the proposed fusion methodology using Directional DCT with PCA and its filtered output has been carried out successfully in terms of the performance evaluation metrics used such as Root Mean Square Error(RMSE), Entropy, Peak Signal to Noise Ratio(PSNR) and Standard Deviation. The obtained fusion results of the respective datasets showing the fused image, error image and the final filtered output image are also displayed above.

Looking at the obtained results, one can observe visually that the filtered output image has improved in quality over the fused output image. Also, the proposed algorithm performance is mostly similar to other commonly used fusion algorithms like DWT and PCA w.r.t. the performance metric results. However, the addition of the 2D filter at the fused output has evidently improved the final enhanced fusion outcome visually as well as performance parameter wise.

Large values of RMSE indicate the larger error in the fused image while larger PSNR values implies a minor differences among the original and the remodelled images. Entropy value of an image points towards the amount of information available on the image. More the entropy , better the image, in terms of S.D., lesser the S.D., better the image.The final filtered outcome observes a significant decline in the RMSE parameter than the proposed hybrid outcome. The Entropy and PSNR values have also improved than the proposed methodology outcome. The Standard Deviation(S.D.) depicting the deviation of output compared to the input has also reduced marginally.

Thus, the overall observation is that though the results obtained are almost similar to the other algorithms, but still filtered fused output has shown slightly better results than the proposed method. One must see that the final fused images usually conserves all the significant information from the two input image.

CHAPTER- 5
CONCLUSION AND THE FUTURE SCOPE

5.1 Conclusion

In this thesis, we proposed a hybrid image fusion algorithm which is based on Directional Discrete Cosine Transform (DDCT) and Principal Component Analysis (PCA) followed by a 2D filter for enhancement purposes and evaluated the obtained results. The source images were distributed in non-overlapping blocks, then fusion is applied to the corresponding blocks of two source images which were to be fused. It is conducted in a 2-stage process, where, firstly, modes 0-8 are applied on the source image and coefficients from the source image for each mode are used in fusion process. Repeat, the same for other modes as well, then, the three different fusion methods are applied for the fusion process.i.e., DDCTavg, DDCTek and DDCTmax between the images. In second stage, eight fused images obtained (one from each mode) after applying fusion rules are fused into a single image using PCA. Then this fused output image is passed through the 2-D filter appended at the end of the algorithm to get an enhanced output.This final filtered outcome is the required output which is compared with the other fusion techniques to get the results.

From the above obtained results and observations and the value of parameters obtained in the qualitative analysis metric tables, it is concluded that though the result of the presented fusion algorithm are not very much different from the already available fusion techniques, still it has shown slight improvement in the filtered output of fused image w.r.t. all quality metric parameters. The overall performance of this algorithm is found to be average with high processing time. DCT based fusion techniques may find its usage in fields where they do not need high precision and quality. DWT based fusion techniques provide superior results,

5.2 Future Scope

In future, we would like to elaborate the research to find the use of other filters in order to enhance the DCT based fusion methods in more effective manner. A lot of improvement and research is required to estimate and calculate the quality of t fused image obtained from a system that may not have a perfect reference image for objective evaluation. Hence, research for the development of new evaluation techniques without using reference image are essential for multi-camera imaging systems.

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