# Comparative Analysis of Various Image Fusion Techniques on Multi-sensor and Medical Images

*Project report submitted in partial fulfillment of the requirement for the degree of*

**BACHELOR OF TECHNOLOGY**

**IN**

**ELECTRONICS AND COMMUNICATION ENGINEERING**


By

Anish Vijan (151005)

Parth Dubey (151065)

UNDER THE GUIDANCE OF

Dr. Shruti Jain




JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY,

WAKNAGHAT

# TABLE OF CONTENTS

# DECLARATION BY THE SCHOLAR

We hereby declare that the work reported in the B-Tech thesis entitled **"Comparative Analysis of Various Image Fusion Techniques on Multi-sensor and Medical Images"** submitted at **Jaypee University of Information Technology, Waknaghat India,** is an authentic record of my work carried out under the supervision of **Dr. Shruti Jain**. We have not submitted this work elsewhere for any other degree or diploma.

Anish Vijan (151005)

Parth Dubey (151065)

Department of Electronics and Communication Engineering

Jaypee University of Information Technology, Waknaghat , India

Date:- May 2019

**JAYPEE UNIVERSITY OF INFORMATIO TECHNOLOGY**

(Established by H.P. State Legislative vide Act No. 14 of 2002)
P.O. Waknaghat, Teh. Kandaghat, Distt. Solan - 173234 (H.P.) INDIA
Website: www.juit.ac.in
Phone No. (91) 01792-257999
Fax: +91-01792-245362

# CERTIFICATE

This is to certify that the work reported in the B.Tech project report entitled **"Comparative Analysis of Various Image Fusion Techniques on Multi-sensor and Medical Images"** which is being submitted by **Anish Vijan and Parth Dubey** in fulfillment for the award of Bachelors of Technology in Electronics and Communication Engineering by the Jaypee University of Information Technology, is the record of candidate's own work carried out by him under my supervision. This work is original and has not been submitted partially or fully anywhere else for any other degree or diploma.

---

**Dr. Shruti Jain**

Associate Professor

Department of Electronics & Communication Engineering

Jaypee University of Information Technology, Waknaghat

# ACKNOWLEDGEMENT

*First of all, we would like to express my deep sense of respect and gratitude towards my advisor and guide **Dr. Shruti Jain**, who has been the guiding force behind this work. We are greatly indebted to her for her constant encouragement, invaluable advice and for propelling me further in every aspect of my academic life. Her presence and optimism have provided an invaluable influence on my career and outlook for the future. We consider it my good fortune to have an opportunity to work with such a wonderful person.*

*She has been great sources of inspiration to us and we thank her from the bottom of my heart. We also extend thanks to all faculty members and staff of the Department of Electronics and Communication Engineering, Jaypee University of Information and Technology, Solan who have encouraged us throughout the course of Bachelors of Technology Degree.*

# Abstract

Image Fusion combines the information from at least two source images from a similar scene to create one single picture containing more exact features of the scene than any of the source images. There are distinctive kinds of picture combination dependent on their applications. For multi sensor picture combination Panchromatic (PAN) mode is utilized, for multi modal picture combination we need to convolute pictures of various sensory systems which is utilized for medical pictures. The target of the paper is to join larger data in a single band with higher spatial data in another informational index. This report principally clarifies the diverse advances utilized in image fusion and how those means were executed. The work performed holds scope for further movements as a lot of research is happening in the field.

Medical diagnosis and ailment for any health problems can be diagnosed accurately by fusing the images related to the problem. Image Fusion combines the data from two source images to create one individual picture containing more exact features of that scene compared to source pictures. There are distinctive kinds of image fusion dependency on their applications. In this reportwe are using different slices; T1 weighted (T1), T1 contrast enhancing (T1ce), T2weighted (T2), and Fluid attenuated Inversion Recovery (Flair) of brain MR images of the same person being fused for diagnosing brain pathology and abnormality. Multiple experiments were conducted by using Discrete Wavelet transform (DWT), Laplacian Pyramid Transform technique and Principle Component Analysis (PCA) fusion techniques. The comparative analysis has been performed on different MR images to make a fused image having more information content. The performance measure considered here includes peak signal to noise ratio, mean square error, and signal to noise ratio. On fusing Flair and T2 slices of brain MR images we get the best results on the basis of SNR and PSNR.

# List of Figures

# List of Tables

# Motivation

The inspiration for Image Fusion research is for the most part because of the contemporary improvements in the fields of multi-spectral, high goals, powerful and image sensor plan innovation. There has been a great deal of progress in ongoing imaging frameworks with the high spatial, goals just as a sensor plan innovation. The answer for data weight can be met by a relating increase in the quantity of preparing units, utilizing quicker Digital Signal Processing (DSP) and bigger memory gadgets. The goals of the progress are as per the following :-

i. Combine higher spatial data in a single band with higher other worldly data in another informational collection :- Combining this data together can give a superior comprehension of the pictures and division sequel of panchromatic picture for information combination.
ii. Sharper Image Resolution (Display) :- The term alludes to the measure of detail a picture holds and is estimated in pixels per inch. The higher the goals, the more pixels per inch. Image goals has an inseparable tie to print your picture.
iii. Improved Classification :- Classification is the most utilized regulated AI strategy. As every one of the many existing characterization calculations can perform inadequately on certain information, various ideas have emerged to improve the first calculations by joining them.

Computing Process manages control of advanced pictures through a computer. It is a subfield of sign and frameworks however center especially aroundpictures. As these centers help in building up a computer framework that can perform preparing on a picture.

# Chapter 1

# INTRODUCTION

People incorporate a exquisite feel of visuals. Eye performs an essential position in assisting numerous human activities. A picture seize of a visual scene always conveys a great deal extra facts than any other description adhered to the scene.

Data fusion is a phenomenon of fusion information from several sources for optimal or compact representation of a huge data supporting better description and decision making. Human brain is a great example for a data fusion system [1].

If we take one sensor such as eyes. It can use beneficial info of a scene by looking within the situation many times. Brain will combine the visuals and discover the information hidden in a single view. More than one perspective will clearly enhance the choices.

Every time we take a picture with our camera, we can no longer be satisfied with a single photo. We strive to take a few extra photos of the equal scene, to have greater readability within the information. It isn't always possible to find that none of the pix include all the required traits. It is not unusual to feel that the wonderful points of these are to be blended to get the favored photo. It motivates us to fuse the snap shots, for a preferred output. We are able to use special cameras and fuse the photographs. Likewise many options are there.

In Biomedical Field Magnetic Resonance (MR) imaging has turned out to be set up as a demonstrative and research device in numerous zones of prescription due to its capacity to give phenomenal delicate tissue outline in various territories of intrigue. Notwithstanding T1-and T2-weighted imaging, many particular MR strategies have been intended to extricate metabolic or biophysical data. Dissemination weighted imaging

gives understanding into the development of water atoms in tissue, and dispersion tensor imaging can uncover fiber introduction in the white issue tracts. Metabolic data about the object of intrigue can be gotten with spectroscopy of protons, notwithstanding imaging of other cores, for example, sodium. Dynamic difference material– upgraded imaging and as of late proton spectroscopy assumes a significant job in oncologic imaging. At the point when these methods are consolidated, they can help the doctor in making a finding or observing a treatment routine. One of the significant points of interest of the diverse sorts of MR imaging is the capacity of the administrator to control picture stand out from an assortment of selectable parameters that influence the sort and nature of the data provided[42]. The components used to get MR pictures and the elements that influence development of a MR picture incorporate MR instrumentation, confinement of the MR flag, slopes, k-space, and heartbeat groupings. There are different slices (T1, T1ce, T2 and Flair) of MR images of brain. The tumor present in the brain can be segmented and classified. Flair slice is mostly used for segmentation. By fusing the different slices, extraction of region of interest (ROI) is easier because fusion gives better results.

Image fusion is approach of combining numerous images from multimodal resources with the information to shape new picture, which incorporates all the common in addition to complementary capabilities of an man or woman photograph[1]. With the quicker developments inside the domain of imaging technology, multisensory structures had got a fact in wide fields inclusive of far flung sensing, medical imaging, machine imaginative and prescient and the army uses. Image fusion gives a powerful way of decreasing this quantity of facts by way of taking out all the useful information from the supply photographs.

Image Fusion is characterized as:

1. *Multiview fusion* of images had come from the equal modality and brought at the same time variaton but from exceptional angles [2].

2. *Multimodal fusion* of images had come from different Sensors (Visible and infrared,multispectral satellite images CT and NMR, or Panchromatic) [2].

3. *Multitemporal fusion* of images are taken at different time variation in order to sense variation between them or to process real images of various objects which were not clicked at a particular time[2].

4. *Multifocus fusion* of images of a 3D scene taken several times with different focal length [2].

5. *Multispectral Fusion*The illustration is especially extremely advanced for the fusion and merging of multispectral pix. For fusion as well as for merging, a strategy is explained. Experiments are accomplished on multispectral images [2].

Image fusion systems are largely classified as single sensor photo combining system (SSIF) and multi sensor photo fusion system (MSIF). In SSIF using a single sensor, collection of pics of the identical scene have been captured and beneficial facts of those numerous photographs is integrated into a single photo by the manner of fusion as shown in Fig 1. In noisy environment and in some illumination conditions, human beings are not able to stumble on the objects of interest which can be effortlessly detected from the combined photos of that targeted scene. Digital photography programs which includes multi-focus imaging and multi-exposure imaging. However, those fusion structures have various drawbacks. They rely upon situations like illumination and dynamic range of the sensors. They are no longer able to seize visually exact images at low illumination condition together with night time, fog and rain.

To overcome the problems of SSIF, MSIF structures have been brought to seize images in worst surroundings conditions. In MSIF, a couple of photographs of the identical scene

are captured using diverse sensors of various modalities are used to gather complementary facts as proven in determine 2. IR sensors are able to seize photographs in low lighting situations. Useful and vital information of these pix at the moment are blended right into a single photograph by way of the process of fusion. Programs consisting of clinical imaging, navy, navigation and hidden weapon detection come under MSIF [3].

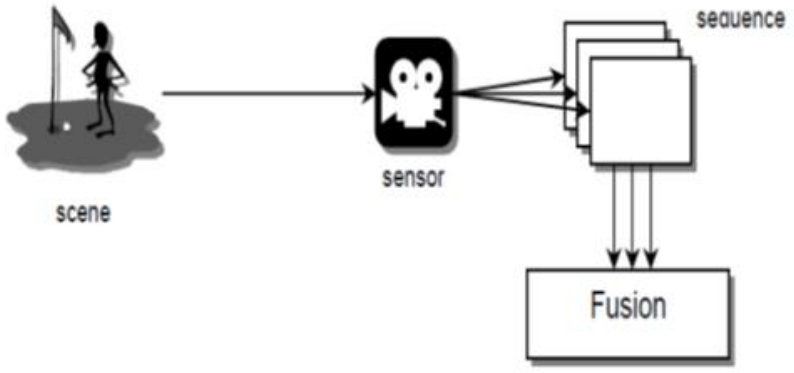



**Fig.1Single Sensor Image Fusion**

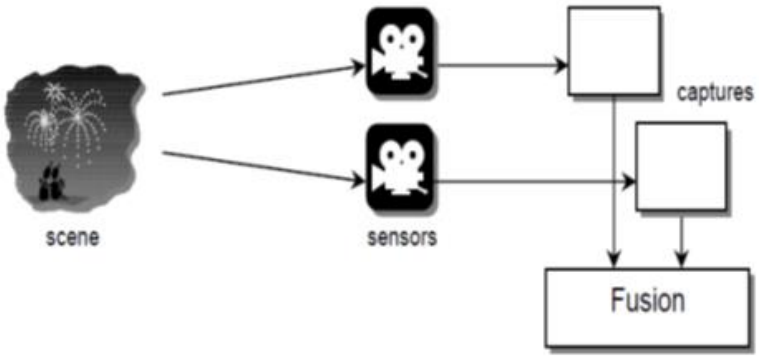



**Fig.2Multi Sensor Image Fusion**

The benefits of multi-sensor image fusion include:

i. Improved Reliability – The combining of two of the measurements are able to lessen noise and substantially improve the reliability of the measured quantity [3].

ii. Robust system performance – Redundant in multiple measurements are used to help in structures robustness. In case one of the extra sensors or the performance of a selected sensor reduces the machine can be depended on the opposite sensors [3].

iii. Compact representation of information – Fusion leads to small representations. For instance in far away sensors, in preference to storing images from variousspectral bands, it is mostly greater useful to comprise the combined statistics [3].

iv. Extended scope of activity – Various sensors that work under exceptional working conditions are sent to the amazing assortment of activity. For instance, particular sensors can be utilized for day and night work purposes [3].

v. Extended spatial and fleeting inclusion – Joint realities from sensors that may change in spatial choice can development the spatial inclusion. The equivalent is legitimate for the worldly estimation [3].

vi. Reduced uncertainty – Joint records from a couple of sensors are able to lessen the uncertainty associated with the sensing or selection method [3].

## 1.1 COLOR SPACES IN IMAGES

1. RGB: RGB is the generally utilized shading zone. RGB represents red green and blue. RGB adaptation expresses, that each shading picture is made of Red photo, Blue photograph, and Green photo. A conventional grayscale picture can be depicted with the guide of handiest one grid, however a shade photograph is made out of three exceptional networks.

One shading picture network = red grid + blue lattice + green framework

This can be best found in Figure 3. The regular uses of RGB model are Liquid precious stone showcase (LCD),Cathode beam tube (CRT), Plasma Display or LED show, for example, a PC screen ,TV, or an expansive scale screen[4].

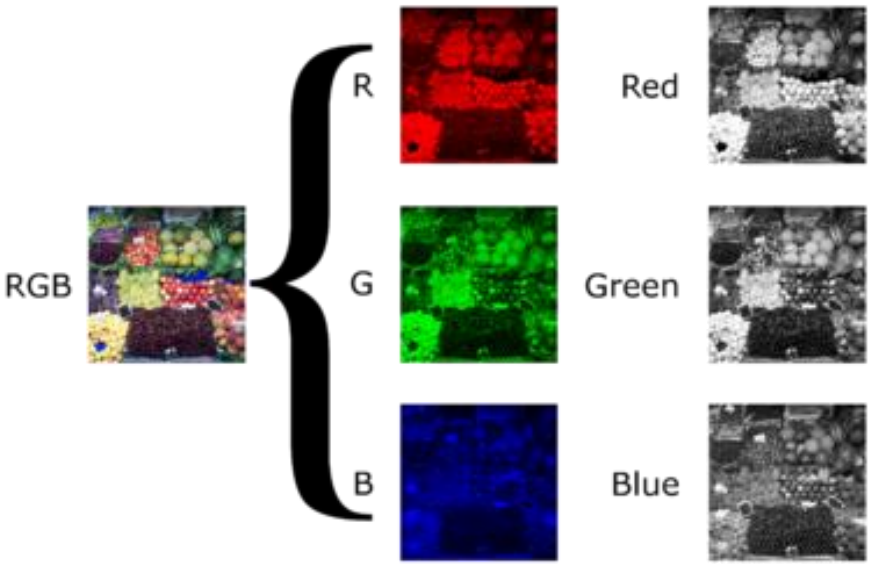



**Fig.3 Gray Scale Factor of the RGB color space**

2. **CMY'K**: To convert from RGB to CMY is done by using method shown in equation 1.

$$\begin{vmatrix} C \\ M \\ Y \end{vmatrix} = \begin{vmatrix} 255 \\ 255 \\ 255 \end{vmatrix} \begin{vmatrix} R \\ G \\ B \end{vmatrix} \qquad \ldots(1)$$

Don't forget we have coloration photo, manner of red, green and blue. Now to convert it into CMY, we should subtract every matrix is subtracted and its respective CMY matrix is stuffed up with the result [4].

3. **Y'UV**:Y'UV defines a coloration space in terms of one luma (Y') and chrominance (UV) additives. The Y'UV shade version is used inside the following composite coloration video standards [4].

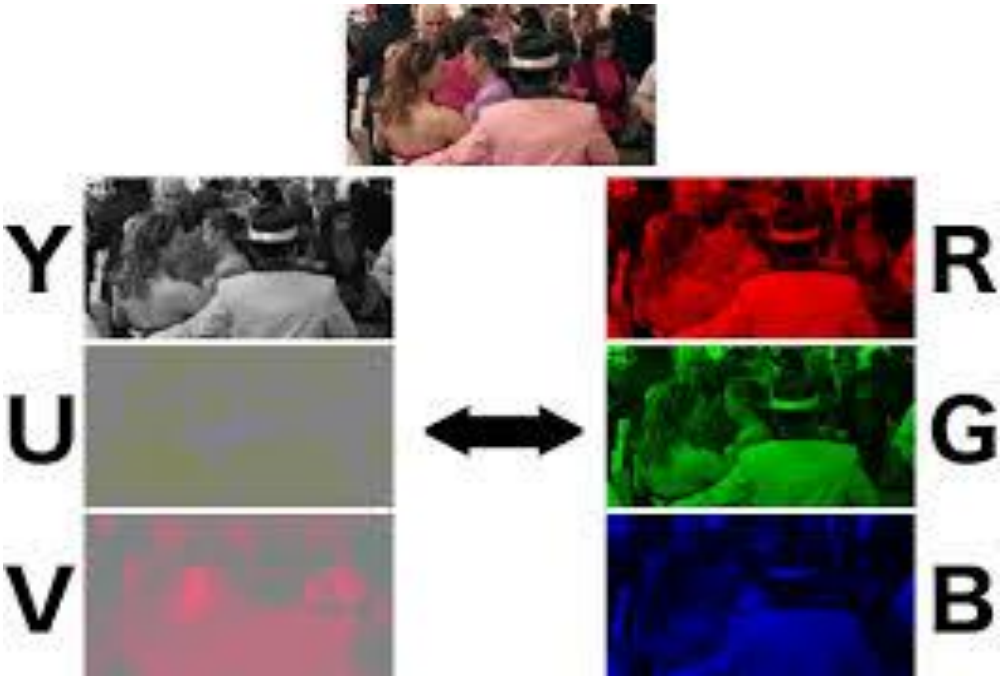



**Fig.4Y'UV components of image [5]**

4. **Y'CbCr**: Y'CbCr color consists of Y' the luma factor and Cb and Cr are the blue-distinction and crimson distinction chroma components too. It is not a fine colored space. It's miles specifically used for virtual structures. Its commonplace applications include JPEG and MPEG compression. Y'UV is regularly used because the term for Y'CbCr, but they're definitely distinct codecs. The primary difference among Y'UV and Y'CbCr is that the former is analog at the same time as the later is virtual [4].

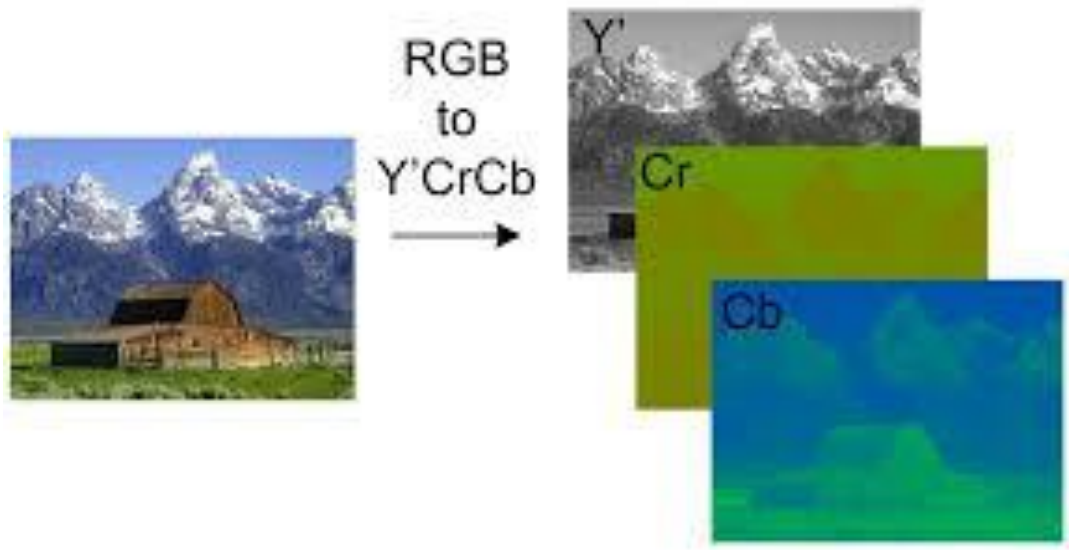



**Fig.5 Y'CbCr components of the image[4]**

## 1.2 FUNDAMENTAL STEPS IN IMAGE FUSION

Fundamental steps used in image fusion process are shown in Figure 1.9. It consists of 5 major steps. 1) Pre-processing, 2) Image registration, 3) Image fusion, 4) Post-processing and 5) Fusion performance evaluation[3].

1. In pre-processing degree, noise or artifacts added in the supply pics all through photo acquisition procedure are completely eliminated.

2. Image registration is a system of arranging multiple pictures of a equal scene in keeping with a co-ordinate gadget. in this procedure, one of the supply photographs are taken as a reference photograph. it is also termed because the constant photograph. Then geometric transformation is implemented on the last source photos to align them with the reference photo.

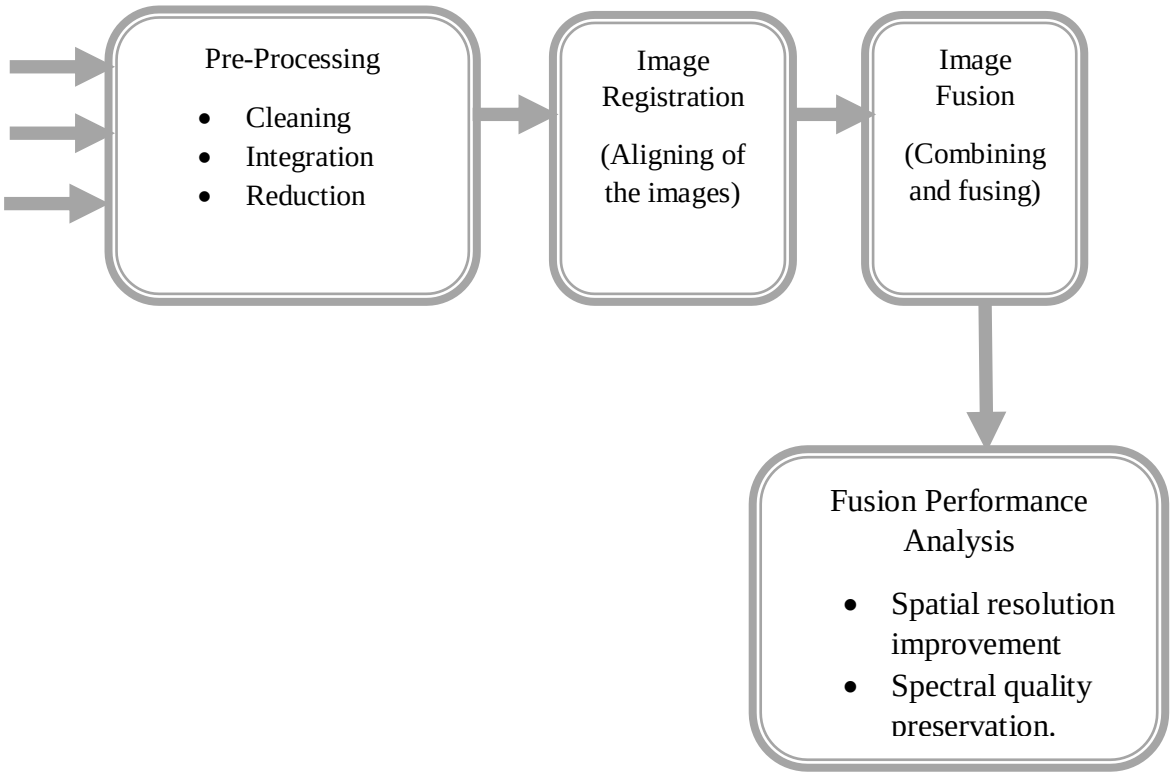



**Fig 6: Proposed Image Fusion Technique**

3. Fusion system may be achieved at 3 tiers pixel, characteristic and selection. Pixel level fusion is achieved on an enter image pixel by means of pixel. But at function stage, fusion is achieved at the extracted capabilities of source pix. At decision degree, fusion is completed on a probabilistic selection facts of neighborhood decision makers. Those decision makers are derived from the extracted functions. Pixel stage fusion schemes are optimum for fusion in comparison to other degree strategies because of their effectiveness and ease of implementation. In this report, our hobby is handiest on pixel level fusion schemes.

4. For the duration of the fusion manner, some required information of source pictures can be lost and visually needless facts or artifacts are added into the fused picture. for this reason, fusion algorithms want to be evaluated for better

performance. This performance evaluation are carried out by way of comparing them qualitatively by visible inspection and quantitatively using fusion metrics.

## 1.3 METHODS TO IMPROVE IMAGE

### 1.3.1 Principal component analysis (PCA)

PCA is a numerical equation that is utilized in the diminishing information measurements. Therefore, the PCA approach lets in the character of principles in measurements and their demeanor in this kind of way that their similitude and varieties are featured. When designs are watched, they might be packed, i.e., their measurements can reduce without loss of information. In exact, the PCA technique might be utilized as a computerized picture pressure calculation with a low dimension of misfortune. In the PCA strategy, the data contained is spared in a computational shape with diminished measurements based absolutely at the pivotal projection of the data set on a subspace produced with the guide of an arrangement of symmetrical methods.

Utilization of the PCA procedure in measurement decrease is legitimized by methods for the simple representation of multidimensional insights, utilizing the information contained in the records covariance framework, thoughts of direct variable based math and essential insights. The exploration performed by methods for Marshall et al (2008) adjusted by methods for the PCA framework in the determinations of pictures from a mixed media database. in venture with Smith, PCA is a real photo pressure calculation with a limiting loss of insights.The overall performance evaluation of the PCA formulation in compressing photographs from the size of the degree of compression and the degree of statistics loss that the PCA introduces into the compressed photos in discarding a few essential additives[5].

The main foremost segment is a solitary hub in space. While every one of the perceptions inside the informational index is anticipated on this pivot, the subsequent qualities shape another variable and the difference of this variable is the most extreme among every single imaginable choice of the essential hub. The second important segment is some other pivot in zone, opposite to the essential. Anticipating the perceptions in this hub creates some other new factor, with the end goal that the fluctuation of this variable is the greatest among every possible decision of this 2d hub. The complete arrangement of essential added substances is as extensive on the grounds that the first arrangement of factors. In well known, the whole of the fluctuations of the essential couple of fundamental segments surpasses 80% of the whole change of the real data. The first actualities might be recuperated from the initial couple of work areas themselves hence the preeminent component assessment is a strategy that permits a lower in the assortment of channels (or groups) by method for diminishing the between channel conditions.

The multidimensional space is mapped right into an area of fewer dimensions by remodeling the authentic area the usage of a linear transformation througha fundamental aspect analysis. The steps concerned in the PCA transform are:

1. Calculate the covariance matrix. The covariance matrix is used inside the case of the unstandardized PCA, even as the standardized PCA makes use of the correlation matrix.

2. The eigenvalues and the eigenvectors from the correlation / covariance matrix are calculated.

3. Important additives of the given data set are eigenvectors of the covariance matrix of the data that is to be entered.

If the correlation matrix of the record is constructed and the eigenvectors discovered and listed in eigenvalue order, then just the first few eigenvectors can be used to reconstruct a big fraction of the variance of the authentic statistics. The first few eigenvectors can often be interpreted in terms of the big-scale physical conduct of the device. The unique area has been decreased to the space spanned through some eigenvectors, with data loss, but maintaining the most essential variance. A lossless dimensionality reduction is feasible if the records in question falls exactly on a smooth, regionally flat subspace; but the noisy information prevents such an actual mapping, introducing a few loss of statistics.

**Mathematical Analysis of the Principal Component Analysis Transform**

Take *N*-dimensional data defined by *X* as,

$$X = [x_1, x_2, x_3 \ldots x_M] \qquad \ldots(2)$$

The first principal component is the n-dimensional vector in the direction, where variance is maximized. The principal component is calculated as the eigenvector of the correlation matrix having the highest eigenvalue. Later mean vector is calculated, which is represented by Equation 3,

$$m_x = \frac{1}{M}\sum_{k=1}^{M} x_k \qquad \ldots(3)$$

where, $m_x$ is the mean vector. The covariance matrix for M vector sample can be calculated from the data by equation 4,

$$C_x = \frac{1}{M}\sum_{k=1}^{M}\left[x_k x_k^T - m_k m_k^T\right] \qquad \ldots(4)$$

where, $T$ = vector transposition, $C_x$ = covariance matrix of order $n$ x $n$.

The $i^{th}$ component of the $x$ vectors in the data, and coefficient ($c_{ij}$) of $C_x$ is the covariance between elements $x_i$ and $x_j$. The covariance is 0, if $x_i$ and $x_j$ are not correlated, therefore, $c_{ij} = c_{ji} = 0$.

Since $C_x$ is symmetric and real, finding a set of n orthogonal eigenvectors always is possible. Let $e_i$ and $\lambda_i$, i = 1, 2 … n, be the eigenvalues and eigenvector of $C_x$, arranged so that

$$\lambda_j \geq \lambda_j + 1 \ for\ j = 1, 2, 3, 4, n - 1$$

$A$ is a matrix whose rows formed from the eigen-vectors of $C_x$ so that the first row of matrix is the eigen-vector of the largest eigen-value and the last row is the eigen-vector of the smallest eigen-value. The matrix $A$ is called the transformation matrix that maps the vectors x into vectors denoted by y as in equation 5:

$$Y = A\ (\ x - m_x) \qquad \ldots(5)$$

This equation is known as the Principal components transform and also;

$$m_y = 0$$

covariance matrix of $y$ can be written in terms of A and $C_x$ given by equation 6:

$$C_y = A.C_x.A^T \qquad \ldots(6)$$

$C_y$ is the diagonal matrix in which elements in the main diagonal are Eigen-values of $C_x$,

$$\boldsymbol{C_y} = \begin{vmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{vmatrix}$$

The off-diagonal elements in covariance matrix are 0, and therefore the elements of y vectors are not correlated. The rows of matrix A are the normalized eigen-

vectors of $C_x$. The principle diagonal element in the $i^{th}$ row of $C_y$ is variance of vector $y_i$. The rows of A being ortho-normal, inverse is its transpose. Thus, one can get the x-vector by doing the inverse transformation in equation 7,

$$x = A^T.y + m_x \qquad \ldots(7)$$

To conclude this section, the principal component analysis is a mathematical way of determining the linear transformation of a sample of points in an N-dimensional space which exhibits the properties of the sample most clearly along the coordinate axes and in this process reduces the inter-channel dependencies. The eigenvalues of each principal component corresponding the amount of total variance in the set described by the component.Fig.7 shows the fusion of two images using the PCA technique

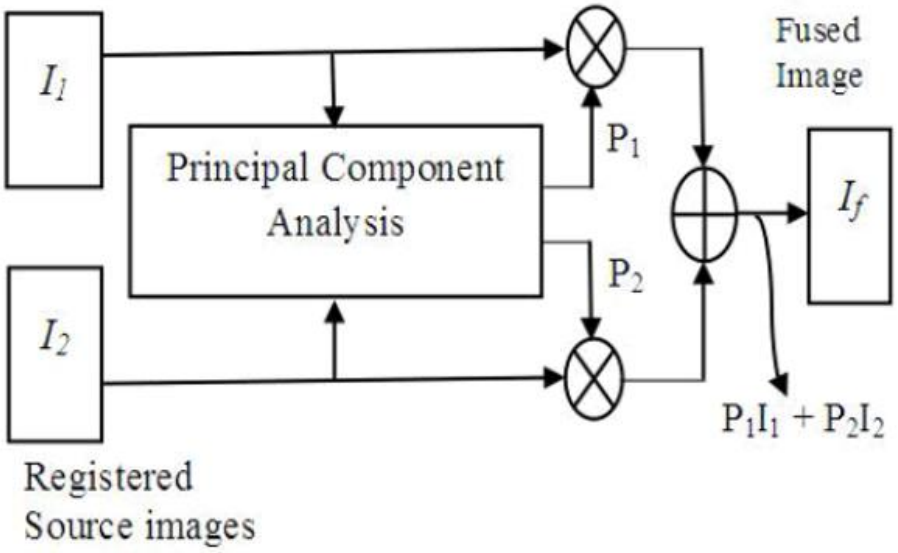



**Fig 7: Flow graph showing the fusion of two images using the PCA technique**

**Advantages of Principal Component Analysis**

1. This is a spatial domain technique of image fusion, wherein works using the pixels. The pixel values are modified to gain the final effects.
2. The belongings of the PCA of transforming the correlated variable into uncorrelated variables this is used for photograph fusion.
3. The redundancy of the statistics is reduced.
4. Big quantities of the inputs are reduced without the actual lack of the records [6] [7] [8] [9].

### 1.3.2 Intensity-Hue-Saturation Method (IHS)

The IHS strategy is a standout amongst the most commonly utilized combination systems for sprucing. It had end up being a standard strategy in photo examination for shading upgrade, include improvement, advancement of spatial choice and the combination of various records units In the IHS space, unearthly records is ordinarily thought about at the tone and the immersion. From the obvious gadget, you can chiefly infer that the profundity interchange has less effect on the data and simple to address. Fusion of the excessive-resolution and multi-spectral sensing snap shots, our purpose is to make certain the spectral records and including the distinct records of excessive spatial decision, therefore, the fusion is even enough for solving in IHS space [8].

Writing proposes numerous IHS change solutions that have been used for changing the RGB format. Indeed, even as unpredictability of the model fluctuates, they produce tantamount qualities for shade and immersion. Be that as it may, the calculations vary inside the technique used in ascertaining the power part of the change.

A power image of IHS framework generally appears like a panchromatic picture and the trademark is utilized in photograph combination framework. The nuts and bolts of IHS combination, in exact, are:

1. Adjust the multispectral photo to panchromatic photo whenever required;
2. Transformation of the multispectral info of picture from RGB to IHS shading space;
3. Alternative the profundity thing by panchromatic photograph with a higher spatial choice;
4. The substituted power component is transformed and one of a kind tone and immersion added substances through turning around to RGB shading space.

This way results in a combined and progressively reasonable unearthly picture. [11, 13]. The power band or factor is supplanted with the guide of the high choice panchromatic picture in the combination. The melded picture would then be able to be gotten through continuing with the invert IHS procedure the utilization of the panchromatic issue along the edge of the H and S added substances. The combined photograph along these lines procured may likewise be a RGB photograph however may also have the spatial detail of the panchromatic picture included into it. [14]

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-1}{\sqrt{6}} & \frac{-1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{6}} & \frac{-2}{\sqrt{6}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$S = \sqrt{{V_1}^2 + {V_2}^2}$$

$$H = \tan^{-1}\left(\frac{V_2}{V_1}\right) \qquad \text{...(8)}$$

### 1.3.3 Discrete wavelet transform (DWT)

The DWT represents the signal in dynamic sub-band decomposition. Technology of the DWT in a wavelet packet sub-band evaluation without the constraint of dynamic decomposition. The discrete wavelet packet remodel (DWPT) is able to carry out an adaptive decomposition of frequency axis. The specific decomposition is selected in line with an optimization criterion. The DWT, primarily based on time-scale representation, presents a good enough multi-decision sub band decomposition of numerous signals. It had come to be a strong device for sign processing and finds several applications in various fields together with audio compression, pattern reputation, texture discrimination, pc photos etc. especially the 2-D DWT and its counterpart 2- D Inverse DWT (IDWT) play an essential function in many photograph/video coding packages. The DWT structure, the input picture is decomposed into excessive pass and coffee pass additives the use of HPF and LPF filters giving rise to the primary stage of hierarchy [15].

**Mathematical Analysis of Wavelet Transform**

Suppose that $\{V_j$ , j belongs to Integer$\}$ is a multi-resolution Analysis in $L^2(R)$, $\varphi(x)$is the scaling function of subspace$V_0$ , $W_j$ is the orthogonal complement of $V_j$ with respect to $V_{j+1}$ , i.e. $V_j + 1 = V_j + W_j$ , $\psi(x)$is wavelet function of subspace $W_0$.

$$f(x) = \sum_n c_n^{j+1} \varphi_{j+1,\,n} \qquad \ldots(9)$$

since $V_{j+1} = V_j + W_j$

$$f(x) = \sum_n c_n^j \varphi_{j,\,n} + \sum d_n^j \psi_{j,n} \qquad \ldots(10)$$

Combining formula (9) with (10), we get equation (11) :

$$\sum_n c_n^{j+1}\varphi_{j+1,n} = \sum_n c_n^j \varphi_{j,n} + \sum d_n^j \psi_{j,n} \quad \ldots(11)$$

Since $\varphi_{j,k}$is orthogonal with respect to different $j$ and $k$ , if two sides of formula Eq. (11) is multiplied by $\varphi_{j,k}$ and then integrated with respect to $x$ , we can obtained equation (12)

$$c_k^j = \sum_n c_n^{j+1}\left\langle \varphi_{j+1,n}, \varphi_{j,k} \right\rangle = \frac{1}{\sqrt{2}} \sum_n h_{n-2k} c_n^{j+1} \quad \ldots(12)$$

Using the same method, we also have:

$$d_k^j = \frac{1}{\sqrt{2}} \sum_n g_{n-2k} c_n^{j+1} \quad \ldots(13)$$

The Eq. (12) and Eq. (13) are the decomposition formula of signal, where $c^j$is an approximation of $c^{j+1}$ , and $d^j$ is the detailed part of $c^{j+1}$and given in equation (14).

$$\begin{aligned} c_n^{j+1} &= \sum_k c_n^j \left\langle \varphi_{j,k}, \varphi_{j+1,n} \right\rangle + \sum_k d_k^j \left\langle \psi_{j,k}, \varphi_{j+1,n} \right\rangle \\ &= \frac{1}{\sqrt{2}} \sum_n c_k^j h_{n-2k} + \frac{1}{\sqrt{2}} d_k^j g_{n-2k} \\ &= \frac{1}{\sqrt{2}} \left( \sum_k c_k^j \tilde{h}_{2k-n} + \sum d_k^j \tilde{g}_{2k-n} \right) \end{aligned} \quad \ldots(14)$$

For two-dimensional signal

$$c_{m,n}^{j} = \frac{1}{2}\sum_{k,l\in Z} c_{k,l}^{j+1} h_{k-2m} h_{l-2n}$$

$$d_{m,n}^{j1} = \frac{1}{2}\sum_{k,l\in Z} c_{k,l}^{j+1} h_{k-2m} g_{l-2n}$$

$$d_{m,n}^{j2} = \frac{1}{2}\sum_{k,l\in Z} c_{k,l}^{j+1} g_{k-2m} h_{l-2n}$$

$$d_{m,n}^{j3} = \frac{1}{2}\sum_{k,l\in Z} c_{k,l}^{j+1} g_{k-2m} g_{l-2n}$$

and its reconstruction formula is represented by Eq.(15) :

$$c_{m,n}^{j+1} = \frac{1}{2}\left(\sum_{k,l\in Z} c_{k,l}^{j}\tilde{h}_{2k-m}\tilde{h}_{2l-n} + \sum_{k,l\in Z} d_{k,l}^{j1}\tilde{h}_{2k-m}\tilde{g}_{2l-n} + \sum_{k,l\in Z} d_{k,l}^{j2}\tilde{g}_{2k-m}\tilde{h}_{2l-n} + \sum_{K,L\in z} d_{k,l}^{j3}\tilde{g}_{2k-m}\tilde{g}_{2l-n}\right) \quad \text{...(15)}$$

For the reconstructionof the signals precisely, the image edges is to be processed with the help of wavelet transform, otherwise the information will be lost.

For left image edges, we have：

$$\begin{cases} c_{-1}^{0} = c_{-2}^{0} = 0 \\ c_{-1}^{1} = \dfrac{h_2}{h_1} d_0^1 \end{cases}$$

For right image edges, we have：

$$\begin{cases} c_{M}^{0} = 0, \quad d_{M/2}^{1} = 0 \\ c_{M+1}^{0} = -\dfrac{h_2}{h_0} c_{M-1}^{0} + \dfrac{h_3}{h_0} c_{M-2}^{2} \end{cases}$$

If the image edges are processed, then the original image can be recovered after wavelet transform in the forward and then backward direction.

### 1.3.4 Laplacian Pyramid Transform

An Image pyramid includes a hard and fast of low bypass or band bypass copies of a photograph, each reproduction representing pattern data of a different scale. Commonly, in an Image pyramid each stage is an element smaller

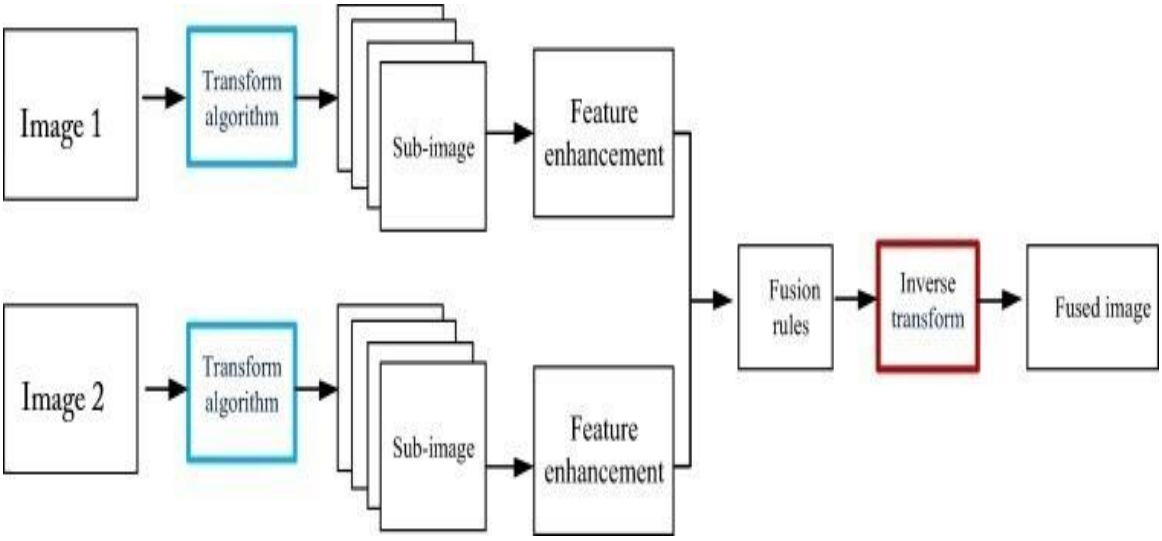



**Fig 8: Flow graph showing the fusion of two images using Laplacian Pyramid technique**

The photos are first deteriorated the utilization of a Laplacian Pyramid disintegration of the first photo into a chain of command of pictures with the end goal that each dimension relates to an alternate band of photo frequencies [16]. The Laplacian pyramid decay is an appropriate MR disintegration for the overall test since it is straightforward, green and higher mirrors the more than one sizes of preparing inside the HVS. The subsequent stage is to process the Laplacian pyramid of the load map. Mixing is then accomplished for every stage separately [16] [17].

*A. Inputs*

The information age way tries to recoup ideal territory perceived as a base one of the photos. By and by, there might be no improving technique this is equipped for remove absolutely the fog results of such debased data sources. in this manner, considering the confinements said previously, given that we procedure best one caught photo of the scene, the arrangement of standards creates from the real photograph best two sources of info that show signs of improvement shade and perceived of the total picture. The essential one better delineates the dimness free zones while the second determined info increments seen subtleties of the dim

territories. Inalienably invigorated by method for the past de a preliminaries form which incorporates Tan [18], Tarel and Hautiere [20] and He et al. [19], look for a strategy so as to pleasantly white.

*B. Weight Maps*

By utilizing best those upgrading activities, they got information sources regardless experience the ill effects of low perceivability particularly in those locales thick murkiness and espresso mellow conditions. The possibility that global appraisal upgrade methods are limited to overseeing dim scenes has been commented already by methods for Fattal [12]. This is a direct result of the way that the optical thickness of murkiness differs all through the image and impacts the qualities in another manner at each pixel. About, the trouble of the general complexity upgrade administrators (for example gamma amendment, histogram evening out, white steadiness) is a result of the truth that these strategies perform (continually) a similar activity all through the entire picture. So as to triumph over this issue, we present three measures. The maps are structured with regards to pixel style to higher characterize the spatial relations of corrupted districts. The weight maps provide the commitment for each information and verify that districts with high correlation or additional saliency from a determined information, get hold of higher qualities [16].

The luminance weight map measures the visibility of each pixel and assigns high values to regions with true visibility and small values to the relaxation. Due to the actuality that foggy pix blessing low immersion, a compelling method to degree this advantages is to assess the absence of vividness. This weight is prepared based absolutely at the RGB shading channel insights. We utilize the well-known things that additional soaked shades yield better qualities in a solitary or two of the shading channels [sixteen]. Photo pyramids were depicted for a multiresolution photo investigation as an adaptation for the binocular combination for human creative and perceptive. A photograph pyramid might be characterized

as arrangement of low or band sidestep duplicates of a special photo wherein both the band limit and example thickness are diminished in regular advances [17]. The Laplacian Pyramid actualizes an "example particular" way to deal with picture combination, all together that the composite photo is developed now not a pixel at any given moment. The essential thought is to play out a pyramid disintegration on each source photo, at that point join a great deal of these deteriorations to shape a composite outline, and in this way reproduce the combined photograph by methods for playing out an opposite pyramid change. The total strategies chooses the perspective example from the source and reproduction it to the composite pyramid, in the meantime as disposing of the less example. Inside the second one, the way midpoints the assets styles. This averaging lessens commotion and gives security in which source pictures contain a similar example data.

## 1.4 IMAGE PERFORMANCE ANALYSIS

A descent quality measure should provide the distortion on the image, for example, blurring, noise or distortion. The fused image is used in the medical analysis, only when it's passed in quality measures make it more defined for diagnostic precision.

1. **Mean Square Error (MSE)-** Mean square error is the most typically used errors projection method where, the error value is the value distinction between the real records and the ensuing facts .The imply of the square of this error gives the error or the real difference among the predicted/best end result to the obtained or calculated end result [21]. The mathematical form of MSE is expressed by Eq. (16)

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}\left(A_{ij} - B_{ij}\right)^2 \qquad \ldots(16)$$

2. **Peak Signal to Noise Ratio (PSNR)**- It is the ratio among the most possible energy of signal and energy of corrupting noise that influences the constancy of its illustration [21]. The PSNR value is written as equation (17):-

$$PSNR = 10log_{10}\left\{\frac{peak^2}{MSE}\right\} \quad \ldots(17)$$

This basically projects the ratio of the highest possible value of the data to the mistake obtained within the statistics. If both the fused and the correct pics are same, then the MSE price might be 0. In that case, the PSNR cost will stay undefined.

3. **Signal to Noise Ratio(SNR)** - It is the quantitative description of the records carried by the radiographic photographs. It is the degree among fused and unique photograph. It measures the ratio between the information and the noise of the fused picture. The higher the ratio the less noisy the background [21]. It is given by the equation (18),

$$SNR = \frac{signal}{RMS\ Noise} \quad \ldots(18)$$

## 1.5 SOFTWARE USED

**MATLAB 2018a**

MATLAB (grid research facility) is a multi-worldview numerical registering condition and restrictive programming language created by MathWorks. MATLAB permits network controls, plotting of capacities and information, usage of calculations, making of UIs, and interfacing with projects written in different dialects, including C, C++, C#, Java and Python.

## 1.6 APPLICATIONS OF IMAGE FUSION IN VARIOUS DEPARTMENTS

1. Fusion is essentially utilized in remote or satellite region for the correct perspective on satellite vision[3]
2. It is utilized in restorative imaging where disease should be investigate through imaging resolution through spatial goals and recurrence perspectives[3].
3. Image combination is utilized in military regions where every one of the points of view used to recognize the different dangers and other goals work based performance [3].
4. For machine vision it is successfully used to imagine the two states after the picture finish up its ideal for the human visualisation [3].
5. In mechanical autonomy field combined pictures generally used to process the recurrence varieties in the perspective on images [3].
6. Image combination is utilized in fake neural systems in 3-D where central length changes as per wavelength [3].

# Chapter 2

# LITERATURE REVIEW

The role of multi-sensor information in bunches of fields alongside far away detecting, medicinal and armed force imaging bundles, picture combination has end up being material inside the region of studies. In remote detecting applications, satellite T.V. for pc MS photograph groups most straightforward give shading information and PAN picture offers the subtleties of the objective individually. in any case, both of these individual previews does never again offer the predefined records of the objective. The primary objective of picture combination is to give new photos that contain both low spatial goals multispectral insights (shading data) and unnecessary spatial choice panchromatic measurements (information). As multi-sensor combination gives broad data while in contrast with unmarried-sensor combination. The utilization of different kinds of sensors may likewise upgrade the lovely of the objective certainties. This part offers with the assorted photograph combination procedures and the significance of reconfigurable equipment for photo combination.

- **Jiang Dong, Dafang Zhuang, Yaohuan Huang and Jingying Fu [22],** given a review of late advances in multi-sensor satellite photograph combination. above all else, they clarified the greatest helpful current picture combination calculations in far away detecting projects that comprise of thing character and class, targets following and trade discovery. They advise us a couple of pointers on progress and improvement of combination calculations for setting up programmed remarkable evaluation conspire.
- **Wu Wenbo, Yao Jing and Kang Tingjun [23],** gotten first rate tasteful measurements in satellite television for pc picture combination by utilizing making multispectral pictures coordinating with topical mapper panchromatic picture, with a blunder oversee of 0.3 pixels. they're ready to utilize Smoothing sift through basically based profundity Modulation (SFIM), adjusted Brovey, high detour get out (HPF),

Multiplication, statute component assessment (PCA) modify and IHS strategies for the photograph combination. They have assessed the nature of melded pictures by methods for the utilization of propose, entropy, prevalent deviation, relationship coefficient with MS photograph and PAN photo as parameters. The outcomes have discovered out of six procedures, HPF and SFIM are the top of the line strategies in holding the otherworldly data of bona fide pix.

- **Yun Zhang and Ruisheng Wang [24],** characterized an idea for thing extraction from high-choice satellite depictions. This procedure incorporates multi ghastly order, photograph combination, trademark division and highlight extraction into the thing Both spatial realities from Panchromatic (PAN) and otherworldly measurements from Multispectral (MS) pictures are utilized for the extraction to improve precision of the proposed strategy and inferred that the proposed idea changed into amazing with accuracy of road network extraction to zero.ninety five which transformed into quite superior to that of various existing street extraction procedures like multispectral characterization.
- **David L. Hall and James Llinas [25],** talked about the multisensor data combination. They brought the multi sensor information combination, moreover referenced that intertwined measurements from numerous sensors gives a few advantages like precise discernibleness and deciding the definite job of an article, than from an unmarried sensor.. Of their view, co-enrollment is the significant thing undertaking in multi-photograph certainties combination. Inside the co-enlistment strategy, the arrangement of or more noteworthy pictures is overlaid all together that every photograph speaks to the equivalent area on this planet.

## 2.1 IMAGE PREPROCESSING

The Earth Observing System Data and Information (EOSDIS) receive raw facts from all of the spacecraft and procedure it to take away telemetry mistakes and remove the

conversation artifacts. Image preprocessing is an initial segment to improve the picture best quality.[19]

- **Yoonsuk Choi, Sharifahmadian E and Latifi S [26],** clarified the value of preprocessing of source pix for satellite picture combination and different aftereffects of preprocessing on photo combination. They have revealed that pre-handling ought to be done well to procure high fine combination results inside the most significant combination process.

## 2.2. Image Registration

At first, the various pictures are in various organize frameworks. The picture enlistment process spatially adjusts the pictures as a source of perspective and afterward changing the pictures each one in turn. Henceforth, a choice of different structure or components in the reference picture and in every one of different pictures is significant so as to decide a fitting change. When the enlistment procedure is finished, the pictures can be additionally prepared for data extraction. The enlistment should be possible both in manual and programmed process. Numerous strategies have been proposed in the picture enrollment.

- **Manjunath B S, Shekhar C and Chellappa R [27],** clarified significance of highlight location in middle degree issues like photo enrollment, thing acknowledgment and face prominence. On this arrangement of guidelines, highlight identification is essentially founded on the exceptional sizes of photograph collaboration adaptation. The trademark finder recognizes the notable photo trademark focuses like line endings, brief follows, corners and other sharp changes in bend. This element recognition is direct and heartiness.

## 2.3 Image Re-sampling

Picture re-sampling is utilized to expand another version of the picture with stand-out pixel measurements to get the significant realities. Re-sampling could be

exceptionally an incredible arrangement needed in light of the fact that, the satellite television for imaging is utilized on a set time spans, while the last yield relies upon the image being at regular spatial lengths. In this way, there's a need to move the legitimate examples of the picture or interject between the enter qualities to accomplish the image tests on the yield places.

Re-sampling is utilized for developing or lessening the size of a picture as an approach to coordinate the qualities of multi-sensor previews. Immediately different the size of the photograph can't blast the measurements in the photo or choice of the picture. In the resampling procedure, the picture attractive hugely relies on utilized introduction approach.

- **Parker, Anthony J, Kenyan, Robert V and Troxel D [28],** thought about unmistakable styles of addition procedures for picture resampling. They examined about an approach to resample the bona fide photo and clarified various sorts of introduction methodologies for picture resampling. along these lines, they inferred that rate of a couple of increment in figuring time, picture tasteful might be progressed by means of resampling the utilization of the high-choice element.
- **Philippe Thevenaz, Thierry Blu and Michael Unser [29],** characterized an overview of introduction procedures for photo resampling. They disclosed addition to speak to a discretionary constant trademark as a discrete whole of weighted and moved combination capacities. They featured different ancient rarities which can ascend while showing up interjection, which incorporate ringing, associating, barricading and obscuring. at some point or another, they've executed esteem execution assessment for insertion techniques.

## 2.4 IMAGE FUSION

In view of the space of activity, pixel level picture combination can be broadly characterized into two kinds, which are spatial area combination strategies and change space combination techniques. Spatial area strategy manage the picture pixels [26]. The pixel esteems are changed to accomplish wanted outcome. Combination strategies, for

example, Averaging, IHS and PCA are a portion of the instances of spatial area procedures.

**2.4.1 Intensity Hue Saturation (IHS)** is a shading combination system. The combination system initially changes a RGB photo into profundity (I) Intensity (H)Hue and (S)Saturation parts. inside the following stage, force (I) is substituted with the high spatial goals panchromatic photo.

- **Firouz Abdullah Al-Wassai, Kalyankar and Ali N V and Al-Zuky A [30],** said that, IHS procedure is one of the comprehensively utilized strategies for photo combination. This test is basically gone for far away detecting bundles, such as intertwining Multispectral (MS) and Panchromatic (PAN) pics.
- **Wen Dou and Yunhao Chen [31]**, referenced that, the principle idea of the IHS technique is fundamentally based at the portrayal of low-goals technique. It appears as an exchange hues between arrangements of resampled and combined multispectral groups. Thus, they gave a histogram coordinating system to maintain a strategic distance from the issue and upgrade IHS strategy in unearthly steadiness.
- **Tu T M, Huang P S, Hung C L and Chang C P [32]**, give a clarification for that if more noteworthy than three MS groups are to be had in IHS changes, a great arrangement is GIHS improve, based on the edges of the MS photographs.

**2.4.2 Principal Component Analysis (PCA)** is a scientific gadget which changes some of associated factors into some of uncorrelated factors. The PCA rebuild changes between connected Multispectral (MS) groups into a fresh out of the box new arrangement of uncorrelated segments. To complete this methodology the fundamental added substances of the MS photo groups are accessible. At that point, the essential fundamental factor which incorporates the most extreme records of the photo is substituted by utilizing PAN photo. at last, the opposite most significant issue changes over the RGB (red, green, and Blue) groups of multi-unearthly picture from the standard parts.

- **ChavezJr P S, Sides S C and Anderson J A [33]** In PCA procedure PAN photograph is substituted to the principal transcendent factor (pc1) likewise for the reason that ghastly contortion inside the intertwined groups is less in PCA contrasted with IHS, however can't be maintained a strategic distance from totally.
- **Naidu V P S and Rao J R [34]**,cited a pixel-degree photo combination the utilization of PCA.. Particular picture combination by and large execution measurements with and without reference picture had been assessed. The simple averaging combination set of guidelines recommends debased execution in contrast with the PCA.
- **NishaGawari and Lalitha Y S [35]** The PCA utilizes a vector space rebuild to diminish the components of huge certainties units. Averaging by methods for utilizing scientific projection the photo diminished into couple of factors (basic parts). They've characterized that, Discrete Wavelet Transform (DWT) changes the photo from the spatial zone to recurrence zone at that point plays out the combination on the changed over coefficients. At last, the mixed picture is taken by method for acting the backwards change. The near examination changed.

**2.4.3 Wavelet Transform** is an augmentation of Fourier hypothesis in n assorted parts and it is added as a chance to the Short-Time Fourier change (STFT). In Fourier revise, the sign is deteriorated into cosines and sines anyway in wavelets the sign is shown on a lot of wavelet capacities. Fourier rebuild gives top notch goals in recurrence region, anyway it isn't constantly proper for non-work area bound markers whose recurrence reaction shift in time. Fundamentally, wavelet change basically based photo combination has 3 stages. The initial step is decay of the enlisted pictures. The second step I s consolidating the redesign coefficients. The third step is reproduction of consolidating revamp coefficients.

- **Gonzalo Pajares and Jesus Manuel de la Cruz [36],** suggested photo fusion to merge data from a couple of pix of identical web page primarily based on wavelet decomposition. The photos may be fused with identical or different resolution degree. They concluded that the wavelet primarily based techniques may be finished with the similar results like classical strategies.
- **Li, Shutao and Kwok, JT-Y and Tsang, Ivor W and Wang, Yaonan [37]** proposed melding pictures with explicit centers the utilization of guide vector machines. Picture combination utilizing help Vector framework (SVM) is some other technique for picture combination that depends on the two wavelets and framework acing approach. It utilizes both SVM and discrete wavelet body changes (DWFT) for combination cause. DWFT deteriorates and extricate trademark coefficients. An improvement in DWT based thoroughly approach is DWFT. The principal qualification of DWFT from DWT is that it introduces an interpretation invariant photo handling and portrayal design. The straightforward strides in strategy the utilization of discrete wavelet outline changes and SVM.
- **Yong Yang [38],** noted photograph combination technique dependent on wavelet revise by the utilization of new procedures for determination coefficients. in the first place, both previews are deteriorated into low recurrence groups and high recurrence groups. At that point the low recurrence groups of both decay pictures are taken by means of side basically based plan and inordinate recurrence groups of every deterioration pictures are taken by utilizing change based thoroughly plot. at last, melded photo is made by methods for a backwards wavelet redesign showing up at the mixed coefficients from each recurrence groups.

**2.4.4 Laplacian Pyramid** (fundamental tool in image processing) of a photograph is a fixed in this technique, the Laplacian pyramids for each image component (IR and visible) are used. A power degree is used to determine from which supply what pixels make contributions at every precise sample location. Take the average of the two pyramids similar to every level and sum them. The resulting photograph is simple common of low resolution photos at every level. Deciphering of a photograph is

completed by using increasing, then summing all of the stages of the fused pyramid which is obtained by means of simple averaging which is basically a sequence of more and more filtered and down sampled variations of a picture.

The method of face detection is finished with the aid of the use of simple and efficient set of rules for multi-attention image fusion called Laplacian pyramid algorithm. Multiresolution sign decomposition scheme is efficaciously used for further packages like gestures, texture, pose and lights conditions whilst taking a picture.

- **Fattal [39]**proposed an algorithm based on impartial factor evaluation. This set of rules below the idea transmissions which are locally uncorrelated, and receives the photo neighborhood albedo and restore image comparison. But, a wonderful lack of sufficient coloration in closely haze pictures can't be treated well.
- **Tan [40]** built up a device for assessing profundity from an unmarried atmosphere corrupted enter picture. empowered by utilizing the truth that assessment is diminished in a foggy photograph, Tan partitioned the photograph into a progression of little fixes and hypothesized that the relating patch in photo should have a superior assessment (wherein evaluation become measured in light of the fact that the total of close-by picture slopes).
- **He [41]**proposed a basic however compelling picture prior darkish channel to remove fog from a solitary enter photo. Be that as it may, on the grounds that the fog imaging adaptation accept normal transmission for all shade channels, this technique may neglect to recuperate pix. Fattal [12] expected each fix has uniform reflectance, and that the approach of the pixels in the fix might be communicated in expressions of shading and transmission. He believed the shading and transmission pointers to be inconsequential and utilized component assessment to appraise the presence of each fix. Great measured advancement in single photo cloudiness disposal has been made in most recent years.

# Chapter 3

# FUNDAMENTAL STEPS OF IMAGE FUSION

The work performed does hold scope for further advancements as a lot of research is happening in the field.

## 3.1 Pre-processing Techniques

Data preprocessing is an information mining approach that includes remodeling raw facts into a comprehensible format. Actual-world statistics is often inconsistent, incomplete and/or lacking in sure behaviors or traits, and is possibly to comprise many errors. Data preprocessing is a technique of fixing such problems.

## 3.2 Image Registration

Image registration is the technique of arranging two or greater photographs of the equal site. One image, called the bottom photograph, is the reference to the alternative pictures, called input photographs, is differentiated. The goal of picture registration is to offer the input picture into association with the base photograph by using making use of a spatial conversion to the enter image. To locate the favored coloration in specific lighting (false Negatives).

## 3.3 Image Fusion

Signal Fusion techniques that can combine data received from different sensors into a single composite image in a feasible and reliable manner.

In IHS combination system initially changes a RGB photo into profundity Intensity (*I*) Hue (*H*) and Saturation (*S*) parts. Inside the following stage, force (I) is substituted with the high spatial goals panchromatic photo.

**Algorithm 1: Image fusion using IHS fusing Technique**

---

**Input:** Multispectral Image

**Output:** Fused image

---

START

Step 1: Adjust the input multispectral image to panchromatic image if required.

Step 2: Transform the input multispectral image from RGB to IHS color space.

Step 3: Higher spatial resolution of pan-chromatic image is used to substitute higher spatial resolution.

Step 4. By reversing to RGB color space transform the substituted intensity part and original hue and saturation components.

END

---

Wavelet change basically based photo combination has 3 stages. The initial step is decay of the enlisted pictures. The second step I s consolidating the redesign coefficients. The third step is reproduction of consolidating revamp coefficients.

**Algorithm 2: Image fusion using DWT fusing Technique**

---

**Input:** High frequency bands fusion of *X* and *Y* images

**Output:** Fused image Z

---

START

Step 1: Reduce LH, HL, HH bands of image X and Y.

Step 2: Calculate spatial frequency of each matrix of picture.

Step 3: Measure frequencies of $X_{\mathrm{LL}}$ and $Y_{\mathrm{LL}}$ and make the i[th] block $Z$ of the combined image as

$$Z_{LL}(m,n) = \begin{cases} Z_{LL}(m,n) SF_{LL}^{x} > SF_{LL}^{Y} + TH \\ Z_{LL}(m,n) SF_{LL}^{x} < SF_{LL}^{Y} - TH \\ \left(\frac{X_{LL}(m,n)+Y_{LL}(m,n)}{2}\right) \; Otherwise \end{cases} \qquad \ldots\ldots\ldots(19)$$

TH is user defined threshold value.

END

---

In Laplacian Pyramid the resulting photograph is simple common of low resolution photos at every level. Deciphering of a photograph is completed by using increasing, then summing all of the stages of the fused pyramid which is obtained by means of simple averaging which is basically a sequence of more and more filtered and down sampled variations of a picture.

**Algorithm 3: Image fusion using Laplacian Pyramidal fusing Technique**

---

**Input:** High-frequency bands fusion of $L_{c1,k}$ *and* $L_{c2,k}$ images

**Output:** Fused image $L_{f,k}$

---

START

Step 1: The two input MR Images are converted into gray-scale images. The gray scale images are passed into the fusion algorithm as the base images of the input for the Laplacian Pyramids.

Step 2: The consecutive REDUCE operation is used to get the corresponding Laplacian pyramids generated for k levels with the zeroth level.

Step 3: Laplacian Pyramids are generated for the corresponding Gaussian pyramids. The Laplacian image is $L_k(i,j)$. As the Laplacian Pyramid has ($k$) levels the Gaussian pyramid will have ($k$+1) levels.

Step 4.Firstly the Laplacian pyramid is generated at the output side. The Laplacian pixel values of the output of every Laplacian image is the value of pixel with its magnitude being the maximum of the two corresponding pixels in the two inputs at the same stage, i.e. for every $k^{th}$ stage of the Laplacian pyramid each pixel is expressed as :

$L_k$ = Laplacian Pyramid function at kth level

$L_{c1,k}$ = Laplacian Image of the first Image

$L_{c2,k}$ = Laplacian Image of the second Image

$$L_{f,k}(i,j) = sign_k(i,j) * \max(|L_{c1,k}(i,j)|, |L_{c2,k}(i,j)| \quad \ldots(20)$$

$$sign_k(i,j) = \begin{cases} sgn\left(L_{c1,k}(i,j)\right), |L_{c1,k}(i,j)| > L_{c2,k}(i,j) \\ sgn\left(L_{c2,k}(i,j)\right), |L_{c1,k}(i,j)| < L_{c2,k}(i,j) \end{cases} \quad \ldots(21)$$

where

$$sgn\left(L_{m,l}(i,j)\right) = \begin{cases} -1, L_{m,l}(i,j) > 0 \\ +1, L_{m,l}(i,j) < 0 \end{cases} \quad \ldots(22)$$

END

---

The PCA rebuild changes between connected Multispectral (MS) groups into a fresh out of the box new arrangement of uncorrelated segments. To complete this methodology the fundamental added substances of the MS photo groups are accessible.

**Algorithm 4: Image fusion using PCA fusion Technique**

---

**Input:** High frequency bands fusion of input images $I_1(x, y)$ and $I_2(x, y)$
**Output:** Fused image Z

---

START

Step 1: The fusion is accomplished by weighted average of images to be fused. Eigen vector related to the largest Eigen value of the covariance matrices of each source are used to obtain weights for each source image. It computes a compress and best description of the data set. The PCA basis vectors like FFT, DCT and wavelet are changing rapidly and its basis vectors depend on the data set.

Step 2: The direction of the maximum variance is used to compute the first principal component. The second principal component is forced to be situated in the subspace vertical (perpendicular) of the first. Inside this subspace, this component points the direction of maximum variance. The third principal component is in the maximum variance direction in the Subspace vertical to the first two and so on. PCA is also known as Hotelling Transform or Karhunen-Loeve transforms.

Step 3: The information flow diagram of PCA-based image fusion algorithm is shown below. The input images (images to be fused) $I_1(x, y)$ and $I_2(x, y)$ are arranged in two column vectors and their empirical means are subtracted. The resulting vector has a dimension of $n$ x 2, where $n$ is length of the each image vector.

Step 4. Compute the eigenvector and eigenvalues for this resulting vector are computed and the eigenvectors corresponding to the larger eigenvalue obtained. The normalized components P1 and P2 (i.e., P1 + P2 =1) are computed from the obtained eigenvector.

The fused image is:

$$\mathbf{If}\ (x, y) = P_1 I_1 (x, y) + P_2 I_2 (x, y)$$

END

---

## 3.4 Image Performance Analysis

In remote sensing, the satellite images are taken from sensors which exhibit either good spectral features (multispectral information) or high spatial features (panchromatic information). Image Fusion is used to increase the explanation of characteristics of images. Drawing out the characteristics and scaling factors is done and best decision is taken regarding the clarity of the data in the image.

# Chapter 4

# IMPLEMENTATION OF IMAGE FUSION ON MULTISENSOR

The work performed does hold scope for further advancements as a lot of research is happening in the multisensor field.

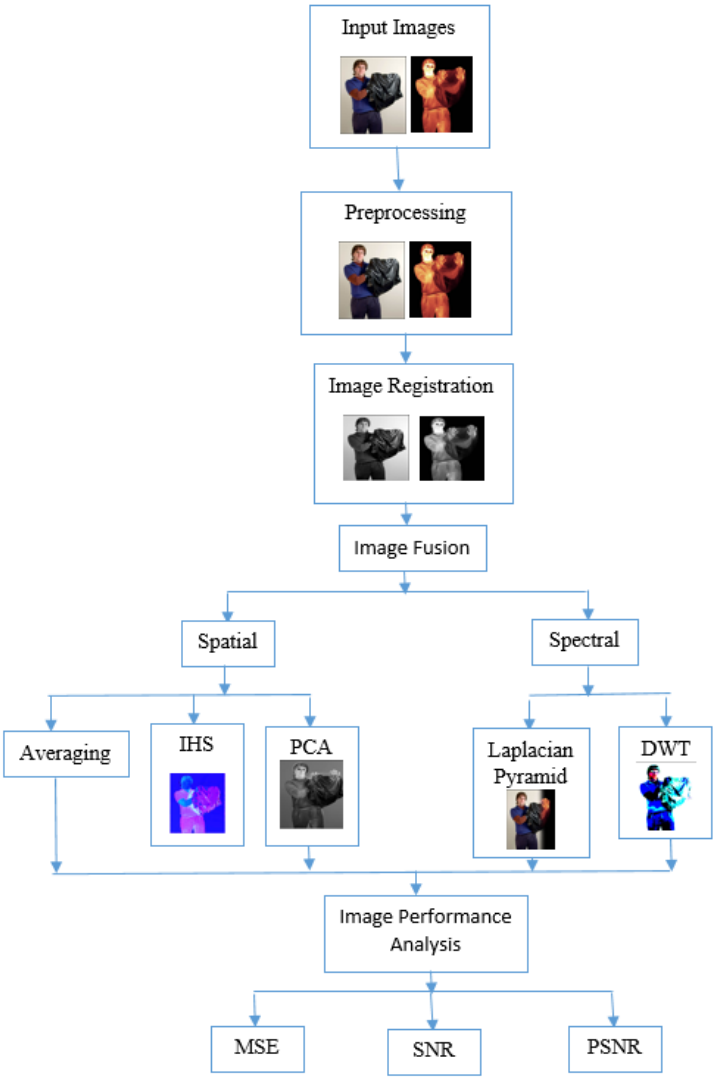



**Fig.9: Proposed Image Fusion Steps in Multi-sensor Images**

## 4.1 Pre-processing Techniques

We have taken image of the same object from different sensors. Fig.10(a)Visible Image, Fig.10(b) IR Image

(a)Visible Image (b) IR Image

**Fig.10 Input Visible and IR Images**

## 4.2 Image Registration

**Gray Scale of RGB of the Visible Image:** Fig 11(a), Fig 11(b) and Fig 11(c) shows thegray scale of red, green and blue components of the Visible Images respectively of size [255 X 255]

(a) (b) (c)

**Fig.11: Gray Scale of RGB of the Visible Image** (a) R component, (b) G component, (c) B component

**Gray Scale of RGB of the IR Image:** Fig 12(a), Fig 12(b) and Fig 12(c) shows thegray scale of red, green and blue components of the IR Images respectively of size [255 X 255].

(a) (b) (c)

**Fig.12: Gray Scale of RGB of the Visible Image**(a) R component, (b) G component, (c) B component

Table 1 **:** Represents the RGB scale of Visible and IR Image

| RGB component | Visible Image | IR Image |
|---|---|---|
| **R** | 219 | 1 |
| **G** | 213 | 1 |
| **B** | 199 | 1 |

Table 1 depicts the various RGB Values of the images of particular pixel

Table 2 **:** Represents the IHS scale of Visible and IR image at

| IHS component | Visible Image | IR Image |
|---|---|---|
| **Normalized I** | 0.77 | 0.003 |
| **Normalized H** | 0.11 | 0.25 |
| **Normalized S** | 0.05 | 0 |

Table 2 depicts the IHS values of the Image of same pixels whose RGB values are calculated

The problems related to the RGB color space are Perceptual unevenness and Chrominance (Color information)mixing and luminance (Intensity information).The IHS color space has the following three components Hue (Influential Wavelength), Saturation (Purity of the color) and Intensity. It uses only single channel to explain color (Hue), making it very intuitive to describe colour. There is extreme dissimilarity in the values of the various color components and therefore improving the quality and the distinction of the color components. There is nochrominance mixing and luminance data. Therefore IHS is preferred for more efficiency and improved quality.

## 4.3Image Fusion

Based on the Algorithm 1 explained in chapter 3, we obtained the fused results of Visible and IR Images shown in Fig 13.

Visible Image IR Image Fused Image

**Fig : 13 Image fusion of Multispectral images using IHS**

Table 3: Performance analysis on Multi-sensor Images using IHS fusion technique

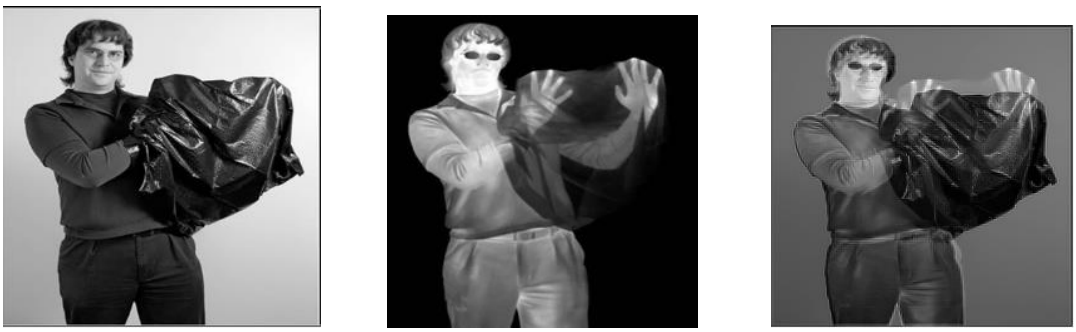
| Images | MSE | SNR(dB) | PSNR(dB) |
|---|---|---|---|
| **Visible Image** | 58.09 | 9.39 | 30.25 |
| **IR Image** | 47.65 | 10.89 | 31.34 |
| **Fused Image** | 150 | 16.144 | 40.04 |

Table 4: Performance analysis on RGB and IHS fused images

| RGB of fused Image | Normalized IHS of fused Image |
|---|---|
| 30 (R) | 0.39 (I) |
| 14 (G) | 0.67 (H) |
| 255 (B) | 0.86 (S) |

From table (1) and table (2) value of I of fused image is betwwen value of I of visible and IR images and value of H and S are both greater than value of H and S of Visible and IR Image .IHS uses just one band to explain color (Hue. There's forceful distinction between the values of the assorted color elements and thus raising the standard. There's no mixture of chrominance and physical property knowledge.

Based on the Algorithm 2 explained in chapter 3, we obtained the fused results of Visible Image and IR Image in Fig 14. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 5.



Visible Image IR Image Fused Image

**Fig 14 : Image fusion of Multispectral images using DWT**

Table 5: Performance analysis using DWT fusing technique on Multisensor Images

| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| **Visible Image** | 58.25 | 9.39 | 30.27 |
| **IR Image** | 47.99 | 10.89 | 31.37 |
| **Fused Image** | 189.82 | 16.144 | 25.38 |

Based on the Algorithm 3 explained in chapter 3, we obtained the fused results of Visible Image and IR Image using Laplacian Pyramid shown in Fig 15. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 6.

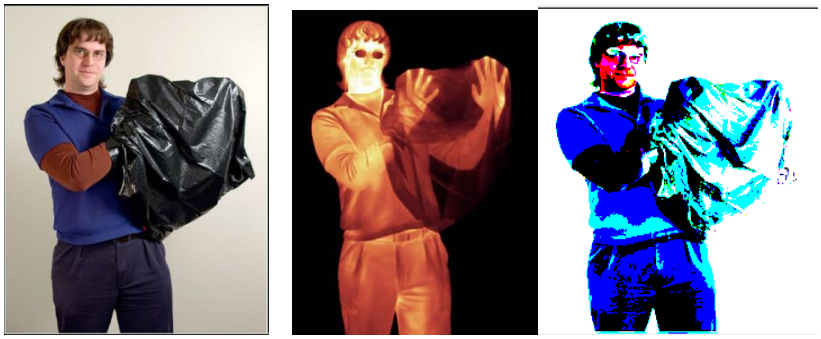
Visible Image IR Image Fused Image

**Fig. 15 : Image fusion of Multispectral images using Laplacian Pyramid**

Table 6: Performance analysis using Laplacian Pyramid on Multisensor Images

| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| Visible | 58.25 | 9.39 | 30.27 |
| IR | 47.99 | 10.89 | 31.37 |
| Fused | 55.56 | 10.01 | 30.60 |

Based on the Algorithm 4 explained in chapter 3, we obtained the fused results of Visible Image and IR Image using PCA shown in Fig 16. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 7.



Visible Image IR Image Fused Image

**Fig.16 : Image fusion of Multispectral images using PCA**

Table 7: Performance analysis using PCA on Multisensor Images

| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| Visible | 58.25 | 9.39 | 30.27 |
| IR | 47.99 | 10.89 | 31.37 |
| Fused | 32.50 | 9.78 | 33.03 |

## 4.4 Image Performance Analysis

If we look at the fused image done with the help of IHS Technique we are unable to differentiate the face of the man. This kind of non-uniformity makes color based segmentation very difficult in this colour space. Further, there is an overall difference between the values of the two images.

Table 8: Performance metrics results of on multi-spectral images using different fusion techniques

| **Fused Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| **HIS** | 150 | 16.144 | 40.04 |
| **PCA** | 32.50 | 9.78 | 33.03 |
| **DWT** | 189.82 | 17.144 | 25.38 |
| **Lap. Pyramid** | 55.56 | 10.01 | 30.60 |

Best thing is that it uses only one channel to describe color (H), making it very intuitive to specify colour. It is Device dependent. There is drastic difference between the values of the various color components and therefore improving the quality and the distinction of the color components. There is no mixing of chrominance and luminance within thedata. Therefore IHS is preferred for more efficiency and improved quality.

On comparing the SNR values of performance metrics we get the best results using DWT technique on fusing multi-spectral images

# Chapter 5

# IMPLEMENTATION OF IMAGE FUSION ONMEDICAL IMAGES

The work performed does hold scope for further advancements as a lot of research is happening in the field.

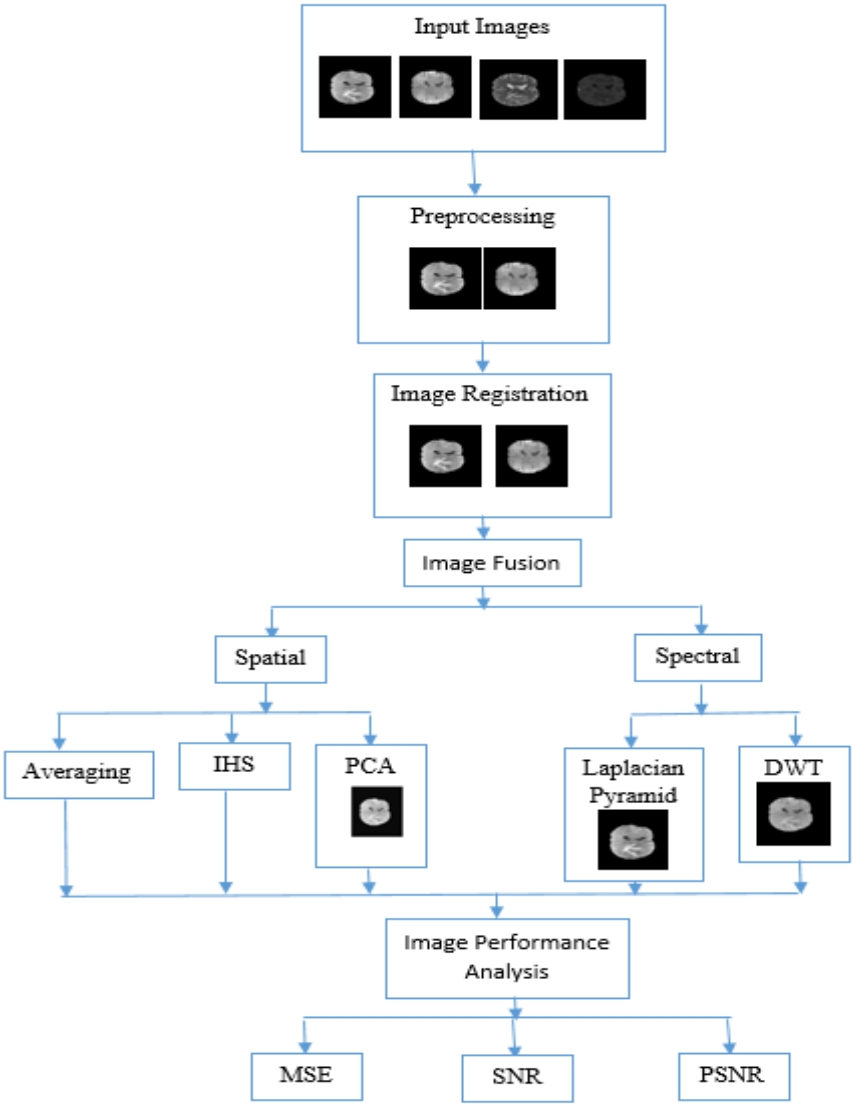
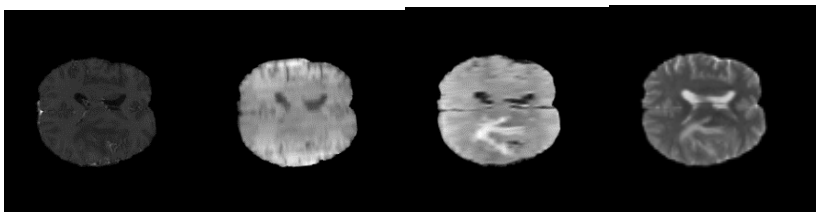



**Fig.17 : Proposed Image Fusion Steps in Medical Images**

## 5.1 Pre-processing Techniques

We have taken MR images with different slices of brain.

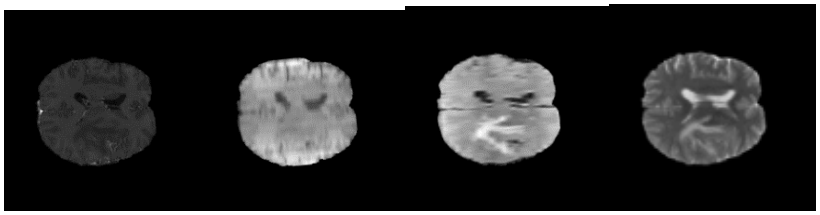


(a) (b) (c) (d)

**Fig 18 : MR images with different slices** (a) T1ce (b)T1 (c)Flair (d)T2

## 5.2 Image Registration

**Gray Scale of Images:** Fig 15(a), Fig 15(b), Fig 15(c) and Fig 15(d) shows thegray scale of MR Images with different slices of brain with size [255 X 255].

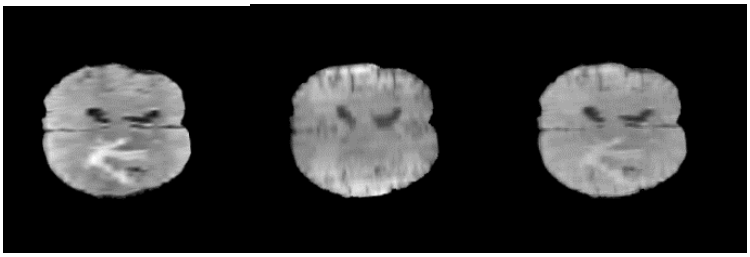


(a) (b) (c) (d)

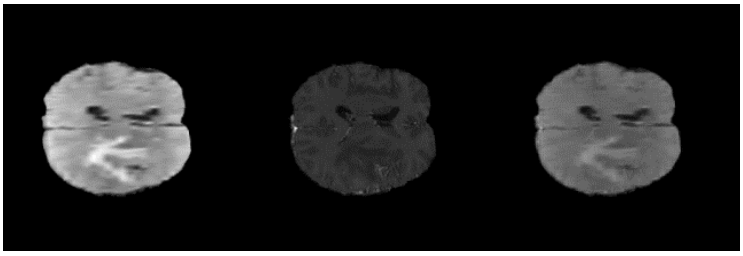
**Fig 19 : MR images with different slices** (a) T1ce (b)T1 (c)Flair (d)T2

## 5.3 Image Fusion

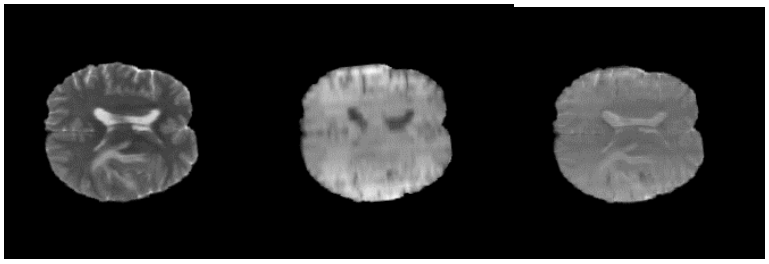
Based on the Algorithm 2, we obtained the fused results of different slices shown in Fig 20. Due to constraint of the space we are showing only combination of four images. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 9.



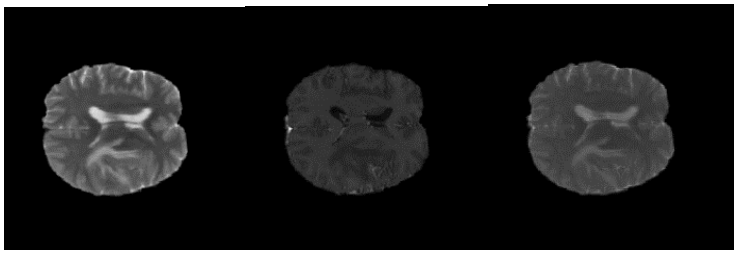
T1ce T1 Fused Image



T1ce Flair Fused Image



T1 T2 Fused Image



Flair T2 Fused Image

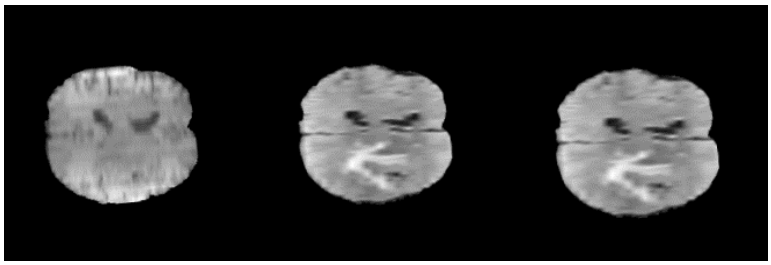
**Fig 20 : Image fusion of MR images of brain using DWT**

Table 9: Performance analysis using DWT fusing technique on Medical Images

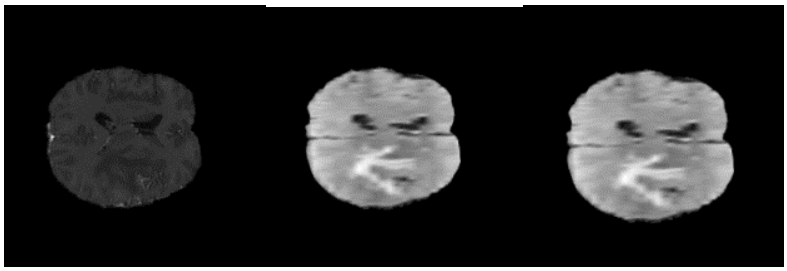
| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| T1ce | 123.91 | 11.20 | 27.23 |
| T1 | 124.17 | 11.46 | 27.22 |
| Flair | 121.77 | 21.26 | 27.31 |
| T2 | 123.22 | 15.11 | 27.26 |
| T1ce + T1 | **125.86** | 10.84 | **27.17** |
| T1ce + Flair | 126.98 | 10.84 | 27.13 |
| T1ce + T2 | 126.76 | 10.84 | 27.14 |
| T1 + Flair | 128.07 | 11.11 | 27.09 |
| T1 + T2 | 129.31 | 11.11 | 27.05 |
| Flair + T2 | 127.27 | **20.91** | 27.12 |

Table 9 depicts that fusing T2 slice and Flair results in highest SNR which can be further used for other applications.

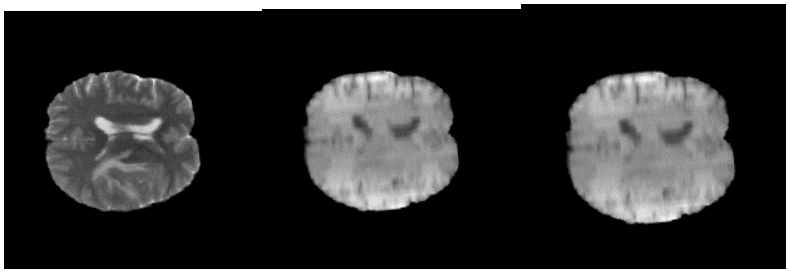
Based on the Algorithm 3 explained in chapter 3, we obtained the fused results of different slices using Laplacian Pyramid shown in Fig 21. Due to constraint of the space we are showing only combination of four images. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 10.



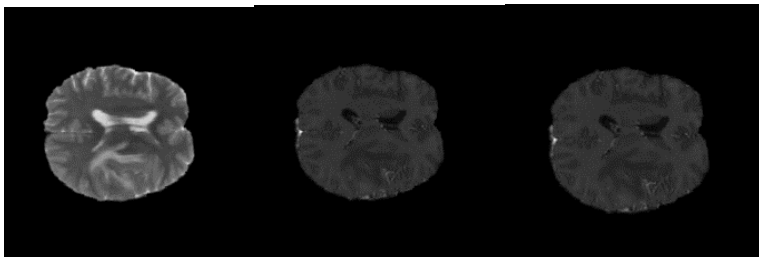
T1ce T1 Fused Image



T1ce Flair Fused Image



T1 T2 Fused Image



Flair T2 Fused Image

**Fig 21 : Image fusion of MR images of brain using Laplacian Pyramid**

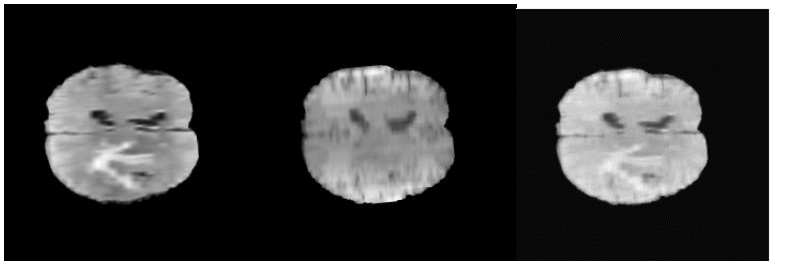
Table 10: Performance analysis using Laplacian Pyramid Medical Images

| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| T1ce | 123.91 | 11.20 | 27.23 |
| T1 | 124.17 | 11.46 | 27.22 |
| Flair | 121.77 | 21.26 | 27.31 |
| T2 | 123.22 | 15.11 | 27.26 |
| T1ce + T1 | 123.67 | 10.01 | 27.24 |
| T1ce + Flair | 124.35 | 13.12 | 27.22 |
| T1ce + T2 | **122.35** | 11.24 | 27.29 |
| T1 + Flair | 124.10 | 12.99 | 27.23 |
| T1 + T2 | 123.63 | 12.39 | 27.24 |
| Flair + T2 | 125.51 | **14.88** | **27.28** |

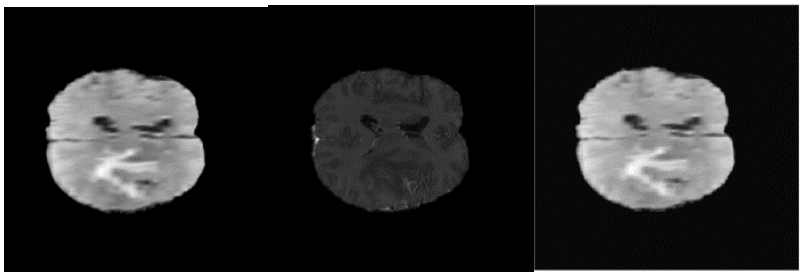
Table 10 depicts that fusing T2 slice and Flair results in highest SNR which can be further used for other applications.

Based on the Algorithm 4, we obtained the fused results of different slices using PCA shown in Fig 22. Due to constraint of the space we are showing only combination of four

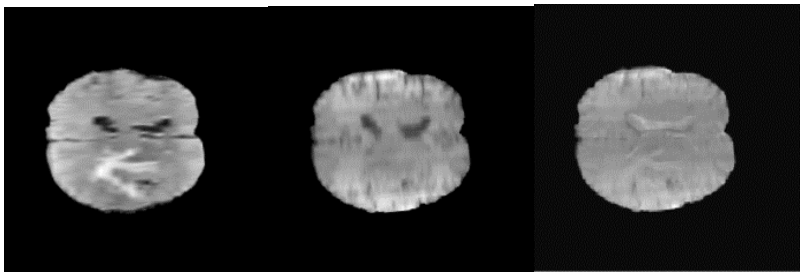
images. The performance parameter was evaluated for individual slices and all the fused images which are shown in Table 11.



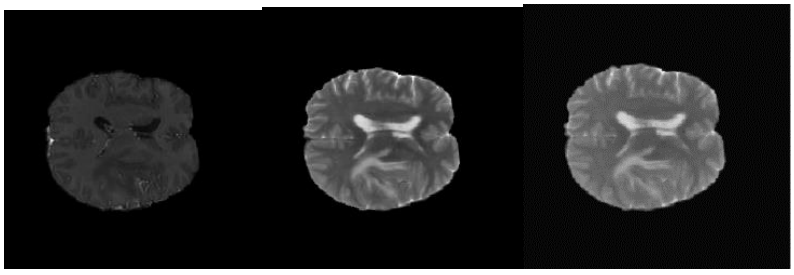
T1ce T1 Fused Image



T1ce Flair Fused Image



T1 T2 Fused Image



Flair T2 Fused Image

**Fig 22 : Image fusion of MR images of brain using PCA**

Table 11: Performance analysis using PCA Medical Images

| **Images** | **MSE** | **SNR(dB)** | **PSNR(dB)** |
|---|---|---|---|
| T1ce | 123.91 | 11.20 | 27.23 |
| T1 | 124.17 | 11.46 | 27.22 |
| Flair | 121.77 | 21.26 | 27.31 |
| T2 | 123.22 | 15.11 | 27.26 |
| T1ce + T1 | 39.06 | 7.34 | 32.23 |
| T1ce + Flair | 38.98 | 7.30 | 32.29 |
| T1ce + T2 | 39.44 | 7.35 | 32.23 |
| T1 + Flair | 41.43 | 7.52 | 31.99 |
| T1 + T2 | 39.45 | 7.38 | 32.20 |
| Flair + T2 | **32.36** | **7.67** | **38.99** |

From Table 11, there is a drastic change in the MSE of the fused image as compared to the Input Images as in PCA we take the limited components and therefore only limited pixels are analysed so we get lowers values of MSE.

## 5.4 Image Performance Analysis

On analysing the various quality analysis performed on different fusion techniques we get the best result on fusing Flair andT2 slices of MR images of brain on the basis of SNR , whereas the PSNR comparison tells the best fusion is T2 and Flair for DWT and PCA whereas T1ce and T1 for laplacian pyramid .

Table 12: Performance metrics results of best fusion using different fusion techniques for SNR

| | **Images** | **SNR(dB)** |
|---|---|---|
| DWT | Flair + T2 | **20.91** |
| Laplacian Pyramid | Flair + T2 | **14.88** |
| PCA | Flair + T2 | **7.67** |

On the basis of MSE we get best results combining the T1ce and T2 for DWT and Laplacian Pyramid and T2 and flair for PCA

# Chapter 6

# CONCLUSION AND FUTURE WORK

We are working on the implementation of various steps for image fusion. There exists difficulties in image fusion coming about because of picture disturbance, targets contrast between pictures, between picture shift between the pictures, absence of fine number of pictures per methodology, great cost of imaging and expanded computing of many-sided quality with expanding picture space and time objectives.To increase the performance, quality and to extract detailed features from the images various steps were followed: Image Registration(arrangement of images), Feature Extraction(Individual and Fused image), and Decision Labelling (Set of Decision maps).

On the basis of the investigation carried out in the present work, the following suggestions are presented for further work and it would beneficial to concentrate on the following issues in future work.

Thetechniques proposed for face detection can be extended forface recognition.

1. The proposed system can be applied to rotated faces and also to detect and recognize faces in pictures (dynamic datasets) and the analysis could be done.
2. The proposed system can be extended to analyse the facial expressions.

Brain image fusion assumes a dynamic job in medical imaging applications by helping the radiologists for detecting the variation from the norm in CT and MRI cerebrum pictures. Different picture combination calculations have been investigated and its execution is assessed for various selections of MRI mind restorative pictures. From the got outcomes it is noticed that on a normal, on analysing the various quality analysis

performed on different fusion techniques on fusing Flair andT2 sliceswe get the best result of MR images of brain on the basis of SNR, although the PSNR comparison tells T2 and Flair is the best fusion for PCA and DWT whereas T1ce and T1 for laplacian pyramid. Comparing MSE we get best results combining the T1ce and T2 for DWT and Laplacian Pyramid and T2 and flair for PCA for MRI brain fusion images. Hence it is concluded that in case of MRI fusion of T1w and T2w images, DWT is giving the best results.

In future data given by image division which is likewise integral. Division results demonstrate what areas in the picture look homogeneous under a picked similarity measure, without thinking about limit normality; while gathering results show which edges in the picture structure customary gatherings that are probably going to relate to remarkable limits. It is sensible to expect that by combining the outcomes delivered by division and gathering of various information should prompt better image-ground division.

# Papers Published

1. Anish Vijan , Parth Dubey, Shruti Jain, "Comparative Analysis of Various Image Fusion Techniques for Brain Magnetic Resonance Images", International Conference on Computational Intelligence and Data Science (ICCIDS 2019), The NorthCap University, Gurugram, September 06-07, 2019. **(Accepted)**

2. Shruti Jain, Mohit Sachdeva, Parth Dubey and Anish Vijan, "Multi-Sensor Image Fusion using Intensity Hue Saturation Technique", 3rd International Conference on Advanced Informatics for Computing Research (ICAICR-2019), Deventure Shimla Hills, Solan Shimla National Highway, Kandāghāt, India on June 15-16, 2019. **(Accepted)**

# References


[1] Mamta Sharma / (IJCSIT) (2016), *International Journal of Computer Science and Information Technologies*,7 (3), 1082-1085.

[2] Jan Flusser, Filip ˇSroubek, and Barbara Zitov´a, *Institute of Information Theory and Automation Academy of Sciences of the Czech Republic Pod vod´arenskou vˇeˇz´ı 4*, 182 08 Prague 8, Czech Republic

[3] Saleha Masood , Muhammad Sharif , Mussarat Yasmin1,Muhammad Alyas Shahid, and Amjad Rehman (2017)**,** *Journal ofEngineering Science and Technology Review*

[4] https://www.tutorialspoint.com/dip/introduction_to_color_spaces.htm

[5] Ramandeep Kaur, Sukhpreet Kaur(2016) , "An Approach for Image Fusion using PCA and Genetic Algorithm" **,** *International Journal of Computer Applications (0975 – 8887)* 145(6)

[6] Reham Gharbia(2014), "Image fusion techniques in remote sensing".

[7] Metwalli, M.R(2009), "Image Fusion Based on Principal Component Analysis and High-pass Filter", *Computer Engineering & Systems. ICCES International Conference* ,pp. 63-70.

[8] V.P.S. Naidu and J.R. Raol(2008), "Pixel-level Image Fusion using Wavelets and Principal Component Analysis", *Defenses Science Journal* , 58(3), pp. 338-352.

[9] Nirosha Joshitha(2012), "Image Fusion using PCA in Multifeature Based Palmprint Recognition", *International Journal of Soft Computing and Engineering (IJSCE)*, 02, Issue-2, pp 226-230.

[10] Changtao Hea, Quanxi Liub, Hongliang Lia, Haixu Wangb(2010), University of Electronic Science and Technology of China, Chengdu 611731, China Southwest institute of technical physics, Chengdu 610054, China , *Symposium on Security Detection and Information Processing*

[11] "Integrating Feedback Retina and IHS Model" *Proceedings of the World Congress on Engineering* 2011 WCE 2011, July 6 - 8, 2011, London, U.K.

[12] Chang Duan, Qihong Huang, Xuegang Wang , Shuai Wang and Hong Wang(2014), "Remote Sensing Image Fusion Based On IHS and Dual Tree

Compactly Supported Shearlet Transform", *International Journal of Signal Processing, Image Processing and Pattern Recognition* 7(5), pp.361-374

[13] T.-M. Tu, S.-C. Su, H.-C. Shyu, P.S. Huang(2001), "A New Look At IHS Like Image Fusion Methods", *Int. J. Information Fusion,* 2(3), pp.177–186.

[14] P. Subramanian, N. R. Alamelu and M. Aramudhan(2015), "Fusion Of Multispectral And Panchromatic Images And Its Quality Assessment", *ARPN Journal of Engineering and Applied Sciences*, 10(9), Issn 1819-6608

[15] Zhu Shu Long , Department of Remote sensing Engineering , Zenghzhou Institute China , presentation.

[16] Codruta Orniana Ancuti and Cosmin Ancuti(2013), "Single image de hazing by multi- scale fusion ieee transactions on image processing", 22(8).

[17] Paresh Rawat, Sapna Gangrade, Pankaj Vyas(2011), "Implementation of Hybrid Image Fusion Technique Using Wavelet Based Fusion Rules",*(IJCTEE),* 1.

[18] R. T. Tan(2008), "Visibility in bad weather from a single image", *in Proc. IEEE Conf. Comput. Vis. Pattern Recognit*, pp. 1–8.

[19] K. He, J. Sun, and X. Tang(2009), "Single image haze removal using dark channel prior", in *Proc. IEEE Conf. Comput. Vis. Pattern Recognit.*, pp. 1956– 1963.

[20] J. Tarel, N. Hauti(2009), "Fast visibility restoration from a single color or gray level image", *Proceedings of IEEE Internation Conference on Computer Vision (ICCV),* Kyoto, Japan: IEEE Computer Society, pp. 2201- 2208.

[21] Varsha Patil, Deepali Sale and M.A.Joshi(2013)**,** *Asian Journal of Engineering and Applied Technology* ISSN 2249-068X, 2(1), pp.40-46

[22] Jiang Dong , Dafang Zhuang, Yaohuan Huang and Jingying Fu(2009), "Advances in Multi-Sensor Data Fusion: Algorithms and Applications" *Sensors,9,* 7771-7784.

[23] Wu Wenbo,Yao Jing∗,Kang Tingjun ,"Study of Remote Sensing Image Fusion and its Application in Image Classification" **,** School Of Geomatics,Liaoning Technical University, 123000, Zhonghua street,Fuxin,China –

[24] Yun Zhang and Ruisheng Wang, "Multi-resolution and multi-spectral image fusion forurban object extraction" ,Department of Geodesy and Geomatics

EngineeringUniversity of New Brunswick15 Dineen Dr., Fredericton, New Brunswick, CANADA E3B 5A3

[25] DavidL.Hall,SeniorMember,"AnIntroductiontoMultisensorDataFusion"IEEE, Tutorial

[26] Yoonsuk Choi*, Ershad Sharifahmadian, Shahram Latifi , "Remote Sensing Image Fusion Using Contourlet Transform With Sharp Frequency Localization"Dept. of Electrical and Computer Engineering, University of Nevada, Las Vegas4505 Maryland Parkway, Las Vegas, NV 89154-4026

[27] R. Chellappa and B. S. Manjunath(2001),"Texture classification and Segmentation: Tribulations Triumphs and Tributes"Foundations of Image Understanding (editor: L. Davis), Kluwer Academic Publishers.

[28] Parker, Anthony J, Kenyan, Robert V and Troxel D, Comparison of Imterpolating methods in Image Resampling , IEEE 2(1) .

[29] Philippe Thévenaz, Thierry Blu and Michael Unser, **"**Image Interpolation and Resampling"Swiss Federal Institute of Technology—Lausanne

[30] Firouz Abdullah Al-Wassai, N.V. Kalyankar, Ali A. Al-Zuky, "The IHS Transformations Based Image Fusion" Research Student, Computer Science Dept., Yeshwant College, (SRTMU), Nanded, India

[31] Wen Dou(2018),Department of Geographic Information Engineering, Southeast University, Nanjing 210096,

[32] M.-J Choi¤*yz* , H.-C. Kim*x*, N. I. Cho*x* and H. O. Kim*z* , "An Improved Intensity-Hue-Saturation Method for IKONOS Image Fusion"Satellite Technology Research Center, Korea Advanced Institute of Science and Technology, Daejeon, 305-701,

[33] Pat S. Chavez, Jr., Stuart C. Sides, and Jeffrey A. Anderson,"Comparison of Three Different Methods toMerge Multiresolution and Multispectral Data"Landsat TM and SPOT Panchromatic*U.* S. Geological Survey, 22(55)North Gemini Drive, Flagstaff, AZ 86001

[34] VPS Naidu and J.R. Raol(2008), "Pixel-Level Image Fusion using Wavelets and Principal Component Analysis – A Comparative Analysis" *Defence Science Journal*,58(3), pp.338-352.

[35] Nisha Gawari and Dr. Lalitha.Y.S(2014)," Comparative Analysis of PCA, DCT & DWT based Image Fusion Techniques" *International Journal ofEmerging Research in Management &Technology* ISSN: 2278-9359 3(5)

[36] Gonzalo Pajares, Jesus Manuel de la Cruz(2004) ,"A wavelet-based image fusion tutorial"Dpto. Arquitectura de Computadores y Autom_atica, Facultad de Ciencias F__sicas, Universidad Complutense de Madrid,Ciudad Universitaria, 28040 Madrid, Spain

[37] Li, Shutao and Kwok, JT-Y and Tsang, Ivor W and Wang, Yaonan(2004), "Fusing images with different focuses using support vector machines, Neural Networks", IEEE Transactions on. IEEE, pp. 1555–1561

[38] Yong Yang, Shuying Huang, Junfeng Gao, Zhongsheng Qian, "Multi-focus Image Fusion Using an Effective Discrete Wavelet Transform Based Algorithm" School of Information Technology, Jiangxi University of Finance and Economics, Nanchang 330013, China,

[39] R. Fattal(2008), "Single image dehazing",*ACM Trans. Graph., SIGGRAPH*, 27(3), p. 72.

[40] R. T. Tan(2008), "Visibility in bad weather from a single image",*in Proc.IEEE Conf. Comput. Vis. PatternRecognit*, pp. 1–8.

[41] K. He, J. Sun, and X. Tang(2009), "Single image hazeremoval using dark channel prior"*in Proc. IEEE Conf.Comput. Vis. Pattern Recognit.*, pp. 1956–1963.