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Novel Hybrid Image Fusion Technique for Medical Imaging

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Abstract
In the current era of technological development, medical imaging plays an important role in various medical diagnoses and clinical treatment applications. The biggest challenge in the medical field is identifying the exact disease and better treatment. In the context of medical imaging, Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) imaging modalities provide diverse information. As the single image does not satisfy sufficient clinical requirements, there is a provision for image fusion. The technique of image fusion for medical issues is devised to eliminate redundancy and increase clinical applicability. It involves the fusing of two or more images with the same or different modalities to acquire the final image with more information than input images. The existing Discrete Wavelet Transform (DWT) or pixel-based fusion techniques did not produce the expected results in terms of edge-preserving, spatial resolution, and shift-invariance. To overcome the limitations of DWT-based fusion techniques, a hybrid image fusion algorithm based on Stationary Wavelet Transform (SWT), Principal Component Analysis (PCA), and Guided filter is proposed in this project.

Index Term – Image fusion, Computed tomography, Magnetic resonance imaging, Reconstruction, DWT, SWT, Guided filter

Introduction

1.1 Image Fusion

Image fusion is the process of combining two or more images into a single image. The resulting image will be more informative than the source images. These images may be captured from different sensors, acquired at different times, or have different spatial and spectral characteristics. With the availability of multi-sensor data in many fields, image fusion has been receiving increasing attention in research or a wide spectrum of applications. Image fusion has been widely used in the military, remote sensing, robot vision, medical image processing and other areas.

Image fusion is type of data fusion, which can be defined as the process of combining two or more source images from the same scene into a composite image with extend information content by using a certain algorithm. The fused image may provide increased interpretation capabilities and more reliable results since data with different characteristics. Moreover, image fusion can be performed at three different processing levels according to the stage at which the fusion takes: pixel, feature and decision level.

1.2 Image Fusion Categories

Image fusion operation can perform in four levels such as pixel level, signal level, feature level and decision level.

Fig 1.1: Image fusion

- In Signal Level Fusion, the signal from different sensors is combined to produce a new signal with better signal to noise ratio than the original signals.
- In Pixel Level Fusion, it performs the operation on every pixel and produces the fused image information from a set of

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pixels in source images to improve the performance of image.

- In Feature Level Fusion, it requires an extraction of objects from various data sources. It requires the information from pixel intensities, edges and textures.
- In Decision Level Fusion, the information is merging at higher level of abstraction and it combines the results from multiple algorithms and finally gets the fused image

1.3 Steps in Image Fusion

The various steps to perform an image fusion operation on image are to obtain the proper effective information is as follows as in Fig 1.2:

(i) First consider the input required images from a single image or from multi-sensor image same scene.

(ii) Split the images into two or more up to n depend upon the requirement.

(iii) Fusion process is applied by using different techniques like NSCT, PCA, DCA etc.

(iv) Finally, the fused image is obtained and it contains all the information, more effective when compared with the input image.

The basic steps of image fusion process are

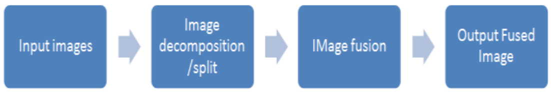

Fig 1.2: Image Fusion Steps

1.2 Image Fusion Techniques

The image fusion techniques can be divided into two ways and are as follows depending upon the requirement[8].

(i) Spatial Domain Fusion Method

(ii) Transform Domain Fusion Method

(i) Spatial Domain Fusion Method

This technique, uses the pixel range of an image. The pixel values are varied to achieve the desired output. The simplest spatial-based method is to take the average of the input images pixel by pixel. However, along with its simplicity, this method leads to several side effects, such as reduced contrast. To improve the quality of the fused image, some researchers have proposed to fuse input images by dividing them into uniform-sized blocks and having those blocks to take the place of single pixels. The spatial domain fusion method is more accurate results are obtained by altering the pixel value in pixel analysis[4].

(ii) Transform Domain Fusion Method

Image fusion is applied in every field such as remote sensing applications, computer vision, and monitoring. The fusion methods are more effective for the vision system. The transform domain fusion method is also called as High Pass Filter based Technique. It allows a high range of pixel ranges and suppresses the low range of pixel values in the image. When compare with the spatial and transform domain fusion methods, the transform domain method has a more effective output of fusion process. In the spatial domain fusion methods, the fusion is directly on pixel gray level or color space from the source images for fusion operation, so the spatial domain fusion methods are also known as the single-scale fusion method. For transform domain-based methods, each source image is first decomposed into a sequence of images through a particular mathematical transformation. Then, the fused coefficients are obtained through some fusion rules for combination. Finally, the fusion image is obtained by means of a mathematical inverse transform. Thus, the transform domain fusion methods are also known as multi-scale fusion methods.

1.3 Existing Methods

There are so many techniques for image fusion process depending up on the requirement and they have some drawbacks. Those methods are as follows[1]:

(i) Intensity-hue-saturation (IHS) transform based fusion
(ii) Principal component analysis (PCA) based fusion
(iii) Multi scale transform based fusion: -

a. High-pass filtering method
b. Pyramid method:
- Gaussian pyramid
- Laplacian Pyramid
- Gradient pyramid
- Morphological pyramid
- Ratio of low pass pyramid

c. Wavelet transforms:
- Discrete wavelet transforms (DWT)
- Stationary wavelet transforms
- Multi-wavelet transforms

d. Curvelet transforms

i. IHS Transform

IHS transform is the oldest method for the image fusion process. Intensity, Hue and saturation are the three properties of colors and give a visibility perception of the image. Hue and Saturation contain more spectral information compare to the intensity of image. This method gives a fused output but not a recent technique.

ii. Principal Component Analysis (PCA)

The advantage of PCA when compared with IHS is it uses an arbitrary number of bands. It is one of the important methods to perform the fusion process. Uncorrelated principal components are formed from low-resolution multispectral images. The first PCA1 component is having the information of the variance and it gives the more effective information of the panchromatic image. Then an inverse PCA is used for the fused image. PCA is a mathematical tool that transforms correlated variables into uncorrelated variables called principal components. It is used in mainly image classification and image compression. The first principal component occurs for the maximum variance in an image and second principal component occurs is at subspace perpendicular to the first component. The third principal component is subspace perpendicular to the first and two and so on. This is the way of occurring the principal components in PCA method.

iii. Multi Scale Transform Based Fusion Pyramid Techniques

It is an old technique for binocular fusion vision systems. By forming a pyramid structure, the original image is represented with the different data levels. A composite image is formed by selecting the pattern approach of the fusion technique. The pyramid decomposition is formed on each and every image. Inverse pyramid transform is used for fused image. Finally, the resultant image will be clarity compare with the above techniques such as PCA, IHS etc. But the contrast will be high of resultant image. So, the visibility precipitance will be low to the normal human observer.

Gaussian Pyramid

The Gaussian pyramid generation is done by starting with an initial image and then lowpass filtering this image to obtain a reduced image. The image is reduced in the sense that both spatial density and resolution are decreased. The low pass filtering is done by a procedure equivalent to convolution by the set of local symmetry weighting function (for example a Gaussian distribution).

In a gaussian pyramid, subsequent images are weighted down using a Gaussian blur and scaled down. Each pixel containing a local average that corresponds to a pixel neighborhood on a lower level of a pyramid, this technique is used especially in texture synthesis.

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Laplacian Pyramid
The Laplacian pyramid is completed as the difference between the original image and the low pass filtered image. Laplacian pyramid is a set of band pass filters it can be used to represent images as a series of band pass filtered images, each sampled at successively sparser density. It is frequently used in image processing and pattern recognition.

Ratio of Low Pass Pyramid
In ratio of low pass pyramid, we take the ratio of two successive layers. The ROLP pyramid is a complete representation of the original image. A ROLP pyramid is constructed for each of the source images. As it is constructed for the composite image from the corresponding nodes in the component pyramids, the one with maximum absolute contrast.

Morphological Pyramid
Morphological pyramids systematically split the input signal in to approximation and detail signals by repeatedly applying morphological filters follow by down sample. The fundamental morphological operators are: erosion, dilation, opening and closing. Consistent analysis of techniques will help in deciding the suitability of a particular technique towards the fusion of large number of images.

Wavelet transforms[2]
Discrete Cosine Transform (DCT)
DCT comprises the images in the form of MPEG, JVG etc. In this transform technique the spatial domain image will be converted into frequency domain image. The 2-dimensional DCT will be applied on gray scale image and the frequency of gray scale image will be converted spatial domain into frequency domain fused DCT coefficients are obtained by the fusion rule. By using the inverse DCT transform the fused image will be obtained. It is one of the most spatial domain fusion methods. These methods are complex and time-consuming process. These are hard to perform. When real time applications, the source images are coded in JPEG and in JPEG format, the fusion approaches are applied in DCT domain is very efficient. The DCT operation is performed on each and every block and it generates 64 coefficients to reduce the magnitude.Those coefficients are rearranged in nonlinear manner for their further encoding process. In case of using spatial domain, the images are decoded and transferred and then after applying fusion procedure the fused image will be coded again.

Stationary Wavelet Transform (SWT)
The stationary wavelet transform (SWT) is an expansion of standard discrete wavelet transform (DWT) that utilizes high and low pass channels. SWT apply high and low pass channels to the information at every level and at next stage it produces two sequences. The two new successions will have same length as that of first grouping. In SWT, rather than annihilation the channels at every level are altered by cushioning them with zeroes. Stationary Wavelet Transform is computationally more complex. The Discrete Wavelet Transform is a time variant transform. The best approach to restore the interpretation invariance is to average some slightly distinctive DWT, called undecimated DWT to characterize the stationary wavelet transform (SWT). SWT does this by suppressing the down-sampling step of the DWT and instead up-sampling the filters by padding with zeros between the filter coefficients. After decomposition, four images are generally furnished (one approximation and three detail coefficients) which are at half the resolution of the original image in DWT[13], whereas in SWT the

approximation and detail coefficients will have the same size as the input images. SWT is like discrete wavelet transforms (DWT), however the main procedure of down- sampling is stifled which implies that SWT is shift invariant. It applies the DWT and excludes both down- sampling in the forward and up-sampling in the reverse direction. More precisely, it executes the transform at each point of the image and saves the detail coefficients and uses the low frequency information at each level.

Discrete Wavelet Transform (DWT)
The discrete wavelet transform (DWT) is a direct transformation that works on an information vector whose length is a whole number power of two, changing it into a numerically diverse vector of the same length. This isolates information into distinctive frequency components, and studies every segment with resolution coordinated to its scale. DWT of an image delivers a non-redundant image representation, which gives better spatial and spectral localization compared to existing multiscale representations. It is computed with a cascade of filters followed by a factor 2 sub sampling and the principle highlight of DWT is multi scale representation. By utilizing the wavelets, given functions can be analyzed at different levels of resolution. DWT decomposition utilizes a course of low pass and high-pass channels and a sub-sampling operation. The yields from 2D-DWT are four images having size equal to half the size of input image. So, from first input image HHa, HLa, LHa, LLa images are obtained and from second input image HHb, HLb, LHb, LLb images are obtained. Here LL image contains the approximation coefficients. LH image contains the horizontal detail coefficients. HL image contains the vertical detail coefficients and HH contains the diagonal detail coefficients. One of the significant disadvantages of wavelet transform is their absence of translation invariance[9 and 10].

Curvelet Transform[3]
In addition to shift-invariance, it has been recognized that an efficient image representation has to account for the geometrical structure pervasive in natural scenes. In this direction the contourlet transform is a multidirectional and multi scale transform that is constructed by combining the Laplacian pyramid with the directional filter bank (DFB) proposed in curvelet transform, which represents edges better than wavelets. The pyramidal filter bank structure of the contourlet transform has very little redundancy, which is important for compression applications. However, designing good filters for the contourlet transform is a difficult task. In addition, due to down samplers and up samplers present in both the Laplacian pyramid and the DFB, the contourlet transform is not shift- invariant.

1.4 Drawbacks of Existing Methods
The existing methods having different drawbacks because of the techniques applied on image as follows:

- They failed under low visibility conditions such as fog, pollution, darkness.
- Resolution of fused image will be less.
- Performance will be less.
- Time consumption is high.
- Delay is also more.
- The complexity of performing operation will be high. processing applications.

1.5 Medical images
Medical images are the scanned images of the human body parts. CT, MRI, FMRI,

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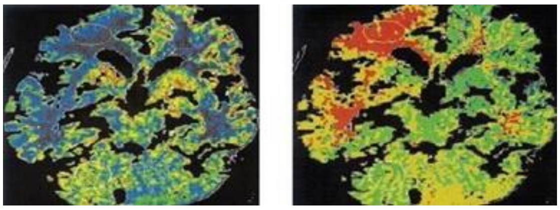
PET, SPECT are some of the medical images which are going to be discussed below.

i. Computerized tomography (CT)

A CT scan, also known as a computed tomography scan or CAT scan, is a medical imaging procedure that uses X-rays and advanced computer technology to produce detailed cross-sectional images of the body. It provides more detailed information than traditional X-rays and can visualize internal organs, bones, soft tissues, blood vessels, and other structures[11].

Fig 1.3: Oblique View of a CT Gantry with an X-Ray Tube, an X-Ray Fan, and Detectors for a Single-Section Scanner and a Multi-Section Scanner(Four Section System Shown)

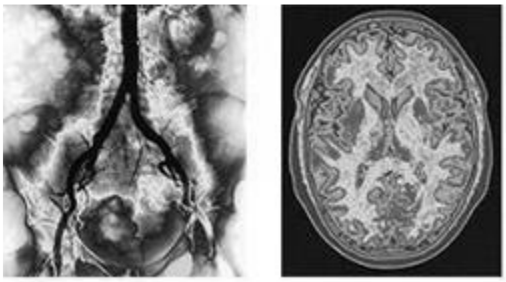


i) ii)

Fig 1.4: i) The Blue Color Shows Total Blood Perfusion Throughout the Brain
ii) The Red Color Shows Blood Perfusion to the Left Side of the Brain

ii. Magnetic resonance imaging (MRI)

MRI stands for Magnetic Resonance Imaging. It is a non-invasive medical imaging technique that uses a strong magnetic field and radio waves to generate detailed images of the body's internal structures. MRI provides valuable information about the body's organs, tissues, and other structures without using ionizing radiation[12].



(i)

(ii)

Fig 1.5: i) Digitally Enhanced MRI Images of the Brain
ii) A 3 Tesla Clinical MRI Scanner

1.8 Applications of Image Fusion in Different Domains

• Remote Sensing

The field of remote sensing is a continuously growing market with applications like vegetation mapping and observation of the environment. The increase in application is due to the availability of high-quality images for a reasonable price and improved computation power. However, as a result of the demand for higher classification accuracy and the need in enhanced positioning precision there is always a need to improve the spectral and spatial resolution of remotely sensed imagery. These requirements can be either fulfilled by building new satellites with a superior resolution power, or by the utilization of image processing techniques. The main advantage of the second alternative is the significantly lower expense. Methods for fusing multispectral lo-resolution remotely sensed images with a more highly resolved panchromatic image are described. The goal is to obtain a high resolution multi spectral image which combines the spectral

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characteristics of the low-resolution data with the spatial resolution of panchromatic image.

• Computer Vision
Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from real world in order to produce numerical or symbolic information, e.g., in the forms of decisions. A Theme in the development of this field has been to duplicate the abilities of human vision by electronically perceiving and understanding an image. This image understanding can be seen as the disentangling of symbolic information from image data using models constructed with aid of geometry, physics, statistics and learning theory. Computer vision has also been described as the enterprise of auto mating and integrating a wide range of processes and representations for vision perception. Applications range from tasks such as industrial machine vision systems which, say, inspect bottles speeding by on production line, to research into artificial intelligence and or computers or robots that can comprehend the document the world around them. The computer vision and machine fields have significant overlap. Computer vision covers the core technology of automated image analysis which is used in many fields.

• Robotics
Mobile roots are providing great assistance operating in hazardous environments such as nuclear cores, battlefields, natural disasters, and even at the nano-level of human cells. These robots are usually equipped with a wide variety of sensors in order to collect data and guide their navigation. Whether a single robot operating all sensors or a swarm of cooperating robots operating their special sensors, the captured data can be too large to be transferred across limited resources (e.g., bandwidth, battery, processing, and response time) in hazardous environments.

• Medical Imaging
Diagnostic imaging lets doctors look inside your body for clues about a medical condition. A variety of machines and techniques can create pictures of the structures and activities inside your body. The type of imaging your doctor uses depends on your symptoms and the part of your body being examined. Each type of technology gives different information about the area of the body being studied or treated, related to possible disease, injury, or the effectiveness of medical treatment. The medical imaging techniques include

- X-rays
- MRI scan
- CT scan etc.

Many imaging tests are painless and easy. Some require you to stay still for a long time inside a machine. This can be uncomfortable. Certain tests involve exposure to a small amount of radiation.

II PROPOSED METHODOLOGY

2.1 Introduction
As a hybrid approach, the proposed method uses two techniques SWT, PCA and Guided filter to get high-contrast better quality images[6].

Decomposition Technique – (SWT):
The SWT is a wavelet transform algorithm designed to overcome the lack of translation-invariance of the discrete wavelet transform (DWT). Translation-invariance is achieved by removing the down samplers and up samplers in the DWT and up sampling the filter coefficients by a factor of in the jth level of the algorithm. The SWT is an inherently redundant the output of each level of SWT contains the same number of samples as the input – so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients. This algorithm is more famously known as "algorithm à trous" in French (word trous means holes in English) which refers to inserting zeros in the filters. By using multi resolution analysis power of SWT is used to decompose the important features of source images into different level. The j level of SWT decomposition is represented as follows:

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$$L_{j+1}(k_x, k_y) = \sum_{l_x=-\infty}^{+\infty} \sum_{l_y=-\infty}^{+\infty} h(l_x)h(l_y)C_{j,k+2j}(l_x, l_y) \quad (1)$$

$$W_{j+1}^{h}(k_x, k_y) = \sum_{l_x=-\infty}^{+\infty} \sum_{l_y=-\infty}^{+\infty} g(l_x)h(l_y)C_{j,k+2j}(l_x, l_y) \quad (2)$$

$$W_{j+1}^{v}(k_x, k_y) = \sum_{l_x=-\infty}^{+\infty} \sum_{l_y=-\infty}^{+\infty} h(l_x)g(l_y)C_{j,k+2j}(l_x, l_y) \quad (3)$$

$$W_{j+1}^{d}(k_x, k_y) = \sum_{l_x=-\infty}^{+\infty} \sum_{l_y=-\infty}^{+\infty} g(l_x)g(l_y)C_{j,k+2j}(l_x, l_y) \quad (4)$$

Where $Lj+1(kx, ky)$ represents the coefficients of approximation of level j. $w^h(kx, ky)$, $w^v(kx, ky)$, $w^d(kx, ky)$ represent the horizontal, vertical and diagonal coefficients of details at level j, respectively. kx = 1, 2, 3, . . ., M and ky = 1, 2, 3, . . ., N. h (lx) and h(ly) are low-pass filters. g (lx) and g(ly) are high-pass filters.

Lj+1 and Cj, k+2 j are the low frequency sub-band at level j and (j+1). lx and ly represent the displacement at x-axis and y-axis[14].

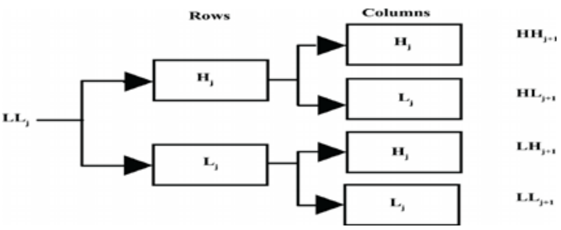

Fig 2.1: Block diagram of SWT

Feature Extraction Technique - (PCA):

sPrincipal Component Analysis (PCA) is a statistical method used to reduce the complexity of a dataset while retaining as much information as possible. It is a type of linear transformation that maps the data onto a new coordinate system where the axes are ordered by their ability to explain the variance in the dataset.

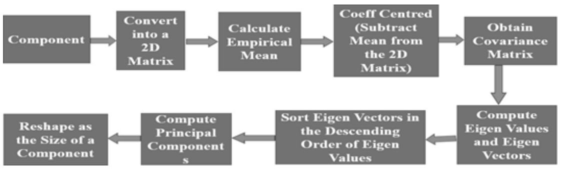

Fig 2.2 Block Diagram of PCA

In PCA, the first principal component is the direction in which the data varies the most, and each subsequent component is orthogonal to the previous ones and captures the remaining variance. The components are ranked in order of their importance, so the first component explains the most variance, and each subsequent component explains less. PCA is commonly used for dimensionality reduction, data compression, and feature extraction in fields such as finance, biology, image processing, and computer vision[15].

2.1 Fusion Rules

Average Rule

It is a well-documented fact that regions of images that are in focus tend to be of higher pixel intensity. Thus, this algorithm is a simple way of obtaining an output imagewith all regions in focus. The value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the corresponding pixel of the output image which is given in equation. This is repeated forall pixel values.

$$K(i,j) = \frac{\{X(i,j) + Y(i,j)\}}{2} \quad (5)$$

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

Maximum and Minimum Rule:

The greater the pixel values the more in focus the image. Thus, maximum algorithm chooses the in-focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel.In minimum rule, the pixel values of the fused image are obtained by selecting the minimum value between the corresponding pixels of the source images. This rule is based on the assumption that the minimum value represents

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the best information from both images and should be retained in the fused image.

$$P(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \max(X(i,j), Y(i,j)) \quad (6)$$

$$P(i,j) = \sum_{i=0}^{m}\sum_{j=0}^{n} \min(X(i,j), Y(i,j)) \quad (7)$$

Where X (i, j), Y (i, j) are two input images and P (i, j) is the fused image.

2.3 Guided Filter

Guided filter is a non-linear image filtering technique that is commonly used in image processing and computer vision. It is a local smoothing filter that uses the content of an input image to guide the filtering process. This means that it is able to preserve edges and fine details in an image while still removing noise and other unwanted artifacts. The guided filter works by computing a weighted average of the pixels in a local neighborhood around each pixel in the input image. The weights are determined by the similarity between the input image and a guidance image, which is typically a smoothed version of the input image. The guided filter can be used for a variety of tasks, such as image denoising, edge-preserving smoothing, and image enhancement.

The guided filter has several advantages over other image filtering techniques. One of its main advantages is its ability to preserve edges and fine details in an image, making it useful for tasks such as image sharpening and enhancement. It is also computationally efficient and easy to implement, making it a popular choice for real-time image processing applications[5 and 7].

• To apply the guided filter to an image, the following steps are typically taken:

(i) Compute the guidance image by applying a smoothing filter (such as a Gaussian filter) to the input image.

(ii) Compute the local means and variances of the input and guidance images within a local window around each pixel.

(iii) Compute the linear coefficients and offset terms for the guided filter using the local means and variances.

(iv) Apply the guided filter to the input image using the computed coefficients and offset terms.

(v) The guided filter can be implemented using various techniques, such as convolution,matrix operations, and recursive filtering.

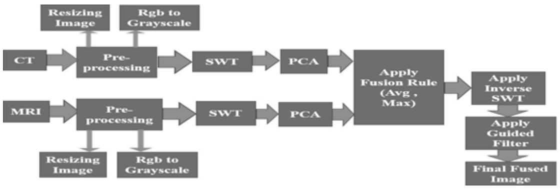

Fig 2.3: Block Diagram of Proposed Method

III Code Implementation

In this chapter, we are going to discuss the steps followed for the implementation of the project. Mainly methodology and code used for this project are explained below. In methodology we can learn about the steps like Image processing, decomposition techniques, feature extraction, fusion and reconstruction. In code explanation section the code corresponding to each section is going to explain.

The pre-requisites of this project are Matrix lab R20XXx, CT and MRI images of size 256 X 256. The experiments are carried out on Intel core i5 computer with 8 GB memory by using MATLAB R2020b.

Methodology

In this we are going to explain the step-by-step process of the proposed technique clearly.

STEP-1: Image Reading and Preprocessing

For this the required dataset should registered in Image Processing Toolbox using MATLAB. By using MATLAB functions, we are going to read the image along with its path and then the image is going to be converted into gray scale image form RGB color space if image is in RGB otherwise no need to modify them. The images are resized to 256 X 256 size. The images are converted to double precision format using the double function to ensure that they can be processed using other MATLAB

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functions that require double precision input. The images are converted to double precision format using the MATLAB function to ensure that they can be processed using other MATLAB functions that require double precision input. SWT decomposition is followed by it.

STEP-2: SWT Decomposition

In this section we are discussing about the SWT algorithm and how it is implemented in this project.

The Stationary wavelet transform (SWT) is a wavelet transform algorithm designed to overcome the lack of translation-invariance of the discrete wavelet transform (DWT). SWT explanation is given in previous chapter decomposition techniques section with the help of formulae and block diagram, refer to Fig 4.1. SWT is a function which is already exist in MATLAB. So, we can the swt () function directly without help of any toolboxes. SWT is used to decompose image into four coefficients or four sub bands. Four sub bands are LL, LH, HL, HH these are also referred to as Approximate, horizontal, vertical and diagonal coefficients. The details of the image are obtained.

STEP-3: PCA Based Feature Extraction

In this section we are discussing about how the best coefficients or features can be extracted from decomposed coefficients produced from SWT technique. This algorithm is implemented by developing a user defined pca function. PCA technique is applied to each coefficient. All these coefficients are passed to the user defined pca function. By using some inbuilt functions like mean (), bsxfun (), cov (), eig () and sort () to perform some operations and produces the mean, Coeff_centred, covariance matrix, eigen values and eigen vectors for each coefficient and finally produces principal components and return to called function.

STEP-4: Fusion Rule

The principal components produced from each coefficient of two images. The principal components obtained from approximate coefficients of two images are fused using averaging rule. The principal components obtained from horizontal, vertical, diagonal coefficients of two images are fused using maximum rule separately using inbuilt function max ().

STEP-5: Image Reconstruction

This step explains about the reconstruction of the image by inverse transform and how they implemented in this project. Reconstruction of the image is the opposite of decomposition of the image. The decomposed pca applied coefficients of CT and MRI images are going to be fused by using inverse transforms. Since the decomposition is done using SWT, the reconstruction is done using inverse SWT. Guided filter is applied to the fused image and contrast is adjusted by adapthisteq (). From the fused image, we can calculate any quantitative parameters. From this fused image the parameters like standard deviation , entropy and mutual information are calculated.

IV Results And Discussions

In this section, we are going to discuss about the results from the execution of code discussed in previous chapter. Here the images of the 2 datasets and the fused images aregoing to show.

The fused image of CT and MRI images is obtained. Different parameters of the fused image are calculated to extract more information from the image. This provides more information in contrast, edge and brightness levels with respect to the individual CT and MRI images. The parameters like standard deviation and entropy obtained from the fused image.

In Table-4.1, Table 4.2 and Table 4.3 we can see the values of parameters for the fused image of two datasets. The parameters listed in this table are entropy, standard deviation and mutual information for two datasets.

In Table 4.4, Table 4.5 and Table 4.6 fused images for two datasets are shown. The fourth column contains the dataset number. The second column contains the CT images in grayscale. The third column contains the

MRI images. The fourth column contains the fused image of respective dataset through this proposed technique.

4.1 Performance Characteristics:

(i) Entropy

The entropy of a system as defined by Shannon gives a measure of uncertainty about the images' actual structure. Shannon's function is based on the concept that the information gain from an event is inversely related to its probability of occurrence. Several authors have used Shannon's concept for image processing and pattern recognition problems. Many used Shannon's concept to define the entropy of an image assuming that an image is entirely represented by its gray level histogram only. As a result, segmentation algorithms using Shannon's function resulted in an unappealingresult, same entropy and threshold values for different images with identical histogram. Shannon defined the entropy of an n-state system as

$$\boldsymbol{H}(\boldsymbol{X}) = -\sum_{i=1}^{n} \boldsymbol{P}_i \, \boldsymbol{log}_2(\boldsymbol{P}_i) \quad \textbf{(8)}$$

Where P_i is the probability.

(ii) Standard Deviation

Standard deviation is a measure of the amount of variability or dispersion in aset of data. It measures how spread out the data is from the mean (average) of the data. Mathematically, the standard deviation (σ) is calculated by taking the square root of the variance (σ^2), which is the average of the squared differences from the mean.

The formula for standard deviation is:

$$\boldsymbol{\sigma} = \sqrt{(\sum(\boldsymbol{x}_i - \boldsymbol{\mu})^2/\boldsymbol{n}} \quad \textbf{(9)}$$

where xi is each individual data point, μ is the mean of the data, and n is the number of data points. The standard deviation is a commonly used statistical tool in many fields, including finance, engineering, and social sciences. It is used to describe the variability of data and to help make predictions and decisions based on that data. A higher standarddeviation indicates more variability in the data, while a lower standard deviation indicatesless variability.

(iii) Mutual Information

Mutual information can also be used as a measure of similarity between two images. The formula for mutual information between two images I and J is:

$$\boldsymbol{MI(I,J) = H(I) + H(J) - H(I,J)} \quad \textbf{(10)}$$

where H(I) and H(J) are the entropies of image I and image J, respectively, and H (I, J) isthe joint entropy of the two images.

Table 4.1: Entropy Parameter for Different Fusion Methods

Fused Image	Methods	Entropy
CT-MRI Set-1	PCA	0.47
	SWT	1.23
	Proposed (SWT+PCA+GF)	**1.26**
CT-MRI Set-2	PCA	0.40
	SWT	1.01
	Proposed (SWT+PCA+GF)	**1.060**

Table 4.2 : Standard Deviation Parameter for Different Fusion Methods

Fused Image	Methods	Entropy
CT-MRI	PCA	0.65
	SWT	0.63

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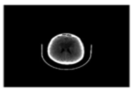
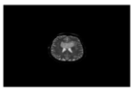
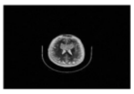
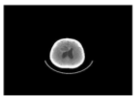
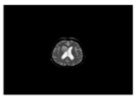
Set-1	**Proposed (SWT+PCA+GF)**	**0.65**
CT-MRI Set-2	PCA	0.58
	SWT	0.56
	Proposed (SWT+PCA+GF)	**0.597**

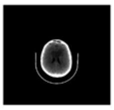
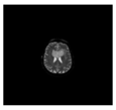
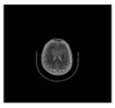
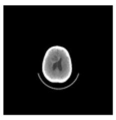
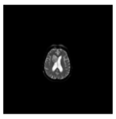
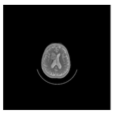
From Table 4.1, Table 4.2 and Table 4.3 it is clearly seen that the entropy, standard deviation and mutual information for all the two datasets have improved to a greater extent for low contrast images through this proposed method.

Table 4.4 : CT-MRI Fused image by Proposed method(SWT+PCA+GF)

Data Set	Input Image 1 (CT)	Input Image 2 (MRI)	Proposed Methodology
1			
2			

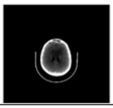
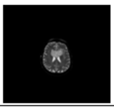
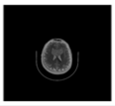
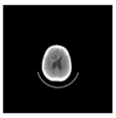
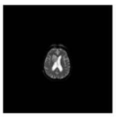
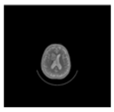
In Table 4.4 the first column represents the dataset number, the second column represents the first input image i.e., CT, the third column represents the second input image i.e., MRI and last column represents fused image of respective images by proposed method

Table 4.5 :CT-MRI Fused image by SWT

Data Set	Input Image 1 (CT)	Input Image 2 (MRI)	SWT
1			
2			

In Table 4.5 the first column represents the dataset number, the second column represents the first input image i.e., CT, the third column represents the second input image i.e., MRI and last column represents fused image of respective images by SWT.

Table 4.6: CT-MRI Fused image by PCA

Data Set	Input Image 1 (CT)	Input Image 2 (MRI)	PCA
1			
2			

In Table 4.6, the first column represents the dataset number, the second column represents the first input image i.e., CT, the third column represents the second input image i.e., MRI and last column represents fused image of respective images by PCA.

V Conclusion

Image fusion is a technique that combines two or more images relevant information from a single image and it contains all the information regarding those input images. This hybrid image fusion method that combines the Stationary Wavelet Transform (SWT), Principal Component Analysis (PCA), and Guided Filter techniques is a promising approach for achieving high-quality image fusion. The SWT is used to decompose the source images into high and low-frequency components, which are then subjected to PCA to extract the essential features for fusion. The guided filter is applied to enhance the edges and preserve the details in the fused image.

From the experimental results analyzed visually and statistically, it is concluded that the resultant image from the proposed method has much better visual quality and the contrast is high as then the fused images from both previous techniques like wavelet-based, and PCA -based methods. In performance metrics such as standard deviation and entropy of image, there exists a significant improvement. Even for low contrast medical images, high contrast fused images are produced by proposed method.

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