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Survey on Multimodal Medical Image Fusion Techniques

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***Abstract*— An Image fusion is the development of amalgamating two or more image of common characteristic to form a single image which acquires all the essential features of original image. Nowadays lots of work is going to be done on the field of image fusion and also used in various application such as medical imaging and multi spectra sensor image fusing etc. For fusing the image various techniques has been proposed by different author such as wavelet transform, IHS and PCA based methods etc.The key objective of vision fusion would be to merging information from multiple images of exactly the same view in order to deliver only the useful information. This paper has centred on the many image fusion techniques. The review has shown that the still much research is needed to improve the image fusion technique further.**

***Keywords*— Multimodal medical image fusion, Medical image, PCA, Wavelet Transform,Non subsampled contourlet Transform**

I. Introduction

Many modern medical sciences need fusion techniques in order to produce images capable of improving clinical diagnosis. The medical image can be classified into high resolution and low resolution, or classified according to sensor device and physical process which is used to generate the images (multi-modality image).Take for example, the CT and MRI images of the brain; each one has high resolution but different multi-modality, the CT provides better analysis in hard tissue while the MRI is more useful in soft tissue. Positron emission tomography (PET) low resolution image contains functional information, while Single Photon Emission Computed Tomography (SPECT) image provides information about visceral metabolism and blood circulation. Fusion process is applied on these images to get a new image containing all texture of the original images as will be proved and discussed in the subsequent parts to come.

Image fusion is an essential subject in vision processing. Image fusion is a process of combining the relevant information from a couple of pictures in to a single image where in fact the resulting merged picture may well be more helpful and complete than some of the input pictures. Picture fusion means the combining of two in to a single picture that has the maximum information content without producing details which are nonexistent in a given picture. With rapid development in technology, it's now possible to obtain information from multi-source pictures to generate a good quality merged image with spatial and spectral information. Caused by vision fusion is a new vision that retains the most desirable information and characteristics of input vision. Several situations in vision processing require high spatial and high spectral resolve in a single vision. Most of the existing equipment is not capable of providing such records convincingly. In remote sensing and in astronomy, multi sensor merging can be used to reach high spatial and spectral resolution by merging visions from two sensors among that has high spatial resolution and the other one high spectral resolution. The key utilization of vision fusion is merging the grey level high resolution panchromatic vision and the coloured low resolution multispectral image. [5] The vision fusion techniques enable the mixture of different information sources. The merged vision may have complementary spatial and spectral resolution features.

When using the vision merging technique, some general requirements should be considered

- The fusion procedure shouldn't discard any information within the source pictures.
- The fusion procedure shouldn't introduce any artifacts or inconsistencies that may distract or mislead a human observer or any subsequent vision processing steps.
- The fusion procedure should be consistent, strong and have, as much as possible, the capacity to tolerate imperfections such as noise or miss registrations.

A) Different Types of Medical Images

In Medical field there are different types of medical scan are available in order to diagnosis a tumour of a patient in absolute manner. Some of the examples of medical scan are CT image, MRI image, PET image and SPECT image.

1) CT Image: A CT Image used to determine information of hard bone and it provides the structure of the body, including internal organs, blood vessels, bones and tumors. CT image is a type of X-ray technology used for broken bones, blood clots, tumors, blockages and heart disease. CT image provides better information about structure of tissue and it is better visualized in CT image.

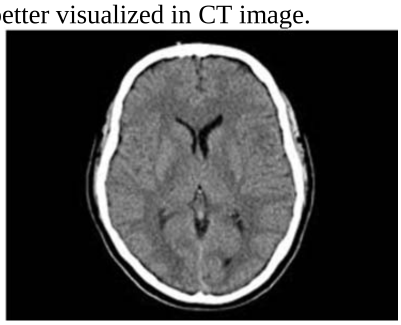

Fig. 1 CT Image

2) MRI Image: MRI image is a type of medical diagnostic imaging used to look at the blood vessels, brain, heart, spinal cord and other internal organs. MRI image provides better information on soft tissue. Normal and Pathological soft tissues are better visualized . The composite image not only provides salient information from both image but also reveal the position of soft tissue with respect to the bone structure. Normally MRI images are typically used to visualize soft tissue information.

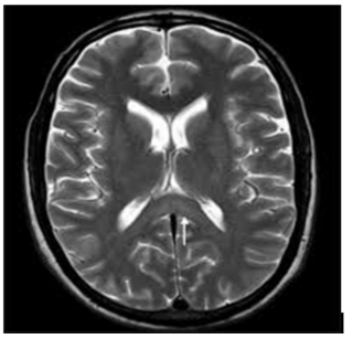

Fig. 2 MRI Image

*3) PET Image:*A PET image shows chemical and other changes in the brain on comparing to that of CT and MRI images [5]. These detailed information of the brain activity of PET image, help doctors to diagnose a problem, choose the best treatment and see how well the treatment is working.

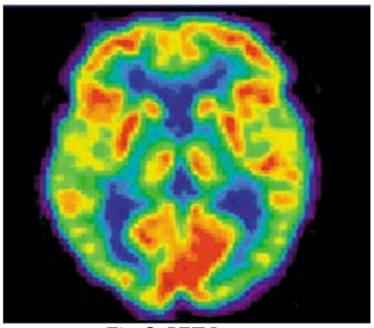

Fig. 3 PET Image

*4) SPECT Image:*A Single Photon Emission Computed Tomography (SPECT) scan is a type of nuclear test that shows how blood flow changes in brain, tissues and organs. The SPECT image differs from a PET image tracer stays in your blood stream rather than being absorbed by surrounding tissues. SPECT scans are cheaper and more readily available than higher resolution PET scans.

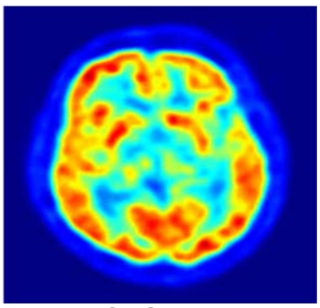

Fig. 4 SPECT Image

B) Different Types of Image Fusion

In image fusion three different levels of image fusion technique are followed. These include Pixel level image fusion, Feature level image fusion and Decision level image fusion. This categorization is based according to merging stage.

1)Feature Level Image Fusion: Feature level image fusion is extracting the feature from different images that are to be fused in order to form a new image.

2)Decision Level Image Fusion: Decision level image fusion contains compact data. It requires the extraction of important features which are depending on their environment such as pixel intensities, edges or textures. These similar features from input images are fused. Decision level image fusion is effective for complicated system which is not suitable for general applications. Decision level fusion consists of merging information at a higher level of abstraction it combines the results from multiple algorithms to yield a final fused decision .

3)Pixel Level Image Fusion: In Pixel based image fusion, the fusion process is performed on a pixel-by-pixel basis. It generates a fused image in which information associated with each pixel is determined from a set of pixels in source images to improve the performance of image processing tasks such as segmentation .Pixel level image fusion is the process which contains detailed information. Most of the medical image fusion process employs Pixel level image fusion due to the advantage of easy implementation, original measured quantity and efficient computation.

II. Literature Survey

In the Image Fusion method the required data from the given supply photographs is merged together to make a composite image whose quality is more advanced than the given feedback images. Picture combination methods could be categorized in to two groups' i.e.

- Spatial domain fusion method
- Transform domain fusion

In spatial domain practices, the pixel price of a picture is immediately dealt with. The pixel values are altered to obtain preferred result. Fusion is required in every area where images are required to be examined. For example, medical image analysis, microscopic imaging, analysis of photographs from satellite, remote sensing request, pc vision and battlefield monitoring. An analysis of remote sensing photographs is being performed utilizing the adjustable quality analysis tool. The distinct wavelet convert is among the important method used for fusion. Strategies like these show increased benefits in spatial and spectral quality of the merged image when compared with different spatial types of fusion. [9]

A. Principal Component Analyses (PCA):

PCA is just a mathematical instrument for change of correlated factors in to uncorrelated factors. For picture classification and picture pressure PCA is used comprehensively. There's involvement of mathematical formula for change of factors which can be called key components. It computes a tight and optimum explanation of the info set. The very first key aspect corresponds to the the maximum amount of difference probable in the info and every subsequent aspect corresponds to the rest of the variance. First key aspect is taken across the direction of optimum variance. The 2nd key aspect is limited to lay in the subspace at a 90 level angle of the first. Within this Subspace, this aspect items the direction of optimum variance. The next key aspect is taken in the optimum difference direction in the subspace at a 90 level angle to the former two. [9]

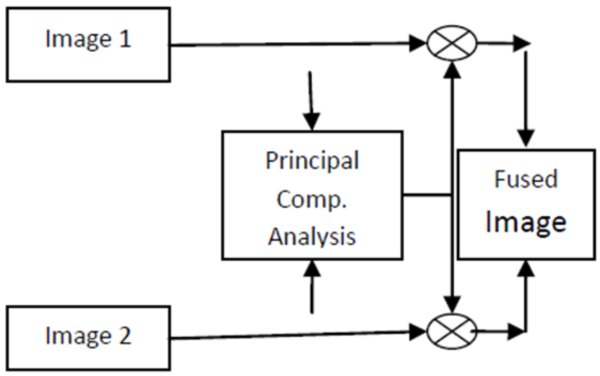

Fig. 5. Image fusion process using PCA

B. Discrete Cosine Transform :

It's seen that all the picture fusion methods are extremely complex and consumes long which are tough to be used on real-time applications. The fusion strategies which are used in DCT domain are extremely effective when the feedback photographs are numbered and merged photographs are restored in JPEG standard .For using the JPEG development, an image (in color or gray scales) is divided in to blocks of 8x8 pixels firstly. The Discrete Cosine Transform (DCT) is a while later used on each block leading to the technology of 64 coefficients that are quantized to decrease their magnitude. The coefficients are then changed into a one-dimensional variety in a crisscross fashion prior to entropy encoding. The compression is obtained in two measures; the initial through quantization and the next through the entropy development process. For reducing the problems undergone in the fusion of real time programs and enhancing the quality of merged picture, DCT fusion strategy is applied. Difference of 8×8 blocks computed from DCT coefficients is used as a comparison qualification for the experience evaluate. [9]

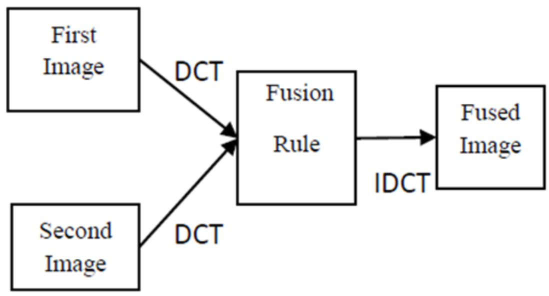

Fig. 6. Image fusion using DCT

C. Discrete Wavelet Transform (DWT) :

In discrete wavelet change (DWT) decomposition, the filters are particularly developed to ensure that successive layers of the chart just contain details which are not presently accessible at the preceding levels. The DWT decomposition works on the cascade of special low pass and high-pass filters and a sub-sampling operation. The components from 2D-DWT are four photographs having measurement add up to half how big is the original picture. [3]

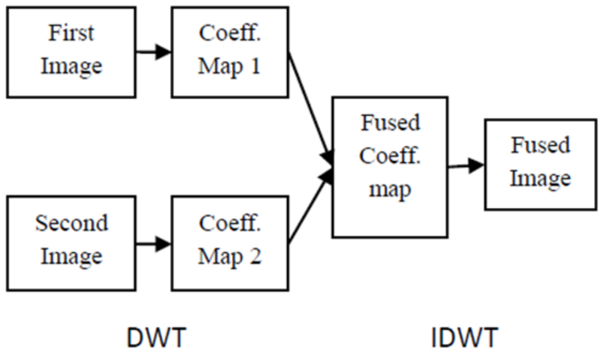

Fig. 7. Image fusion using DWT

D. Dual Tree Complex Wavelet Transform:

In this method, fusion is executed using the masks to remove information from the decomposed structure of DT-CWT [11]. Figure8 demonstrates the complex transform of a signal using two split DWT decompositions: Tree a and Tree b. It can be observed that the DT-CWT structure, involves both real and complex coefficients. It is known that DT-CWT is relevant to visual sensitivity. Fusion procedure involves the formation of a fused pyramid using the DT-CWT coefficients which are obtained from the decomposed pyramids of the source images. The fused image is obtained through conventional inverse dual tree complex wavelet transform or reconstruction process. This results show a significant reduction of distortion. Resulting fused image is obtained by performing inverse transform of combined coefficient map which shows the oriented nature of complex wavelet sub bands. That is each of the clock hands in different directions is taken correctly by the differently oriented sub bands. In the figure 9 shown the area of region of image more in focus has larger magnitude coefficient. i.e. by comparing each and every pixel of both images the values of larger magnitude coefficient alone is taken. Maximum scheme is used to produce the combined coefficient map. It thus takes only the larger coefficient from images to produce the combined coefficient map. Resulting fused image is obtained by performing inverse transform of combined coefficient map which shows the oriented nature of complex wavelet sub bands. That is each of the clock hands in different directions is taken correctly by the differently oriented sub bands. Coefficient fusion rule is applied to magnitude of DT-CWT coefficients as they are complex. Experiment results show that this fusion method is remarkably better than the classical discrete wavelet transform.

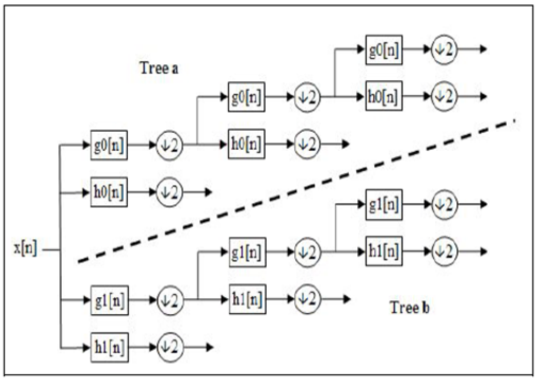

Fig. 8. Image fusion using DT-CWT

E. Non-Subsampled Contourlet Transform (NSCT) :

The NSCT is a fully multi-scale, multi-direction and shift invariant expansion of contourlet transform [6]. It is a fast implementation process. It is a type of tool in order to provide a better representation of the contours. NSCT has an important property of image decomposition [8]. It achieves similar sub band decomposition as similar to that of contourlets, but without down samplers and up samplers in it. Because of its redundancy, the filter design problem of the NSCT is much less constrained than that of contourlets. This enables us to design the filters with better frequency selectivity for achieving a better sub band decomposition. Using the mapping approach we provide a framework for filter design that ensures good frequency selectivity in addition to having a fast implementation through sequential steps . The NSCT has proven to be very efficient in image noise removal and image enhancement. NSCT can be divided into two stages for decomposing the medical images. First stage is Non Subsampled Pyramid (NSP) and Second, Non-Subsampled Directional Filter Bank (NSDFB) stage.

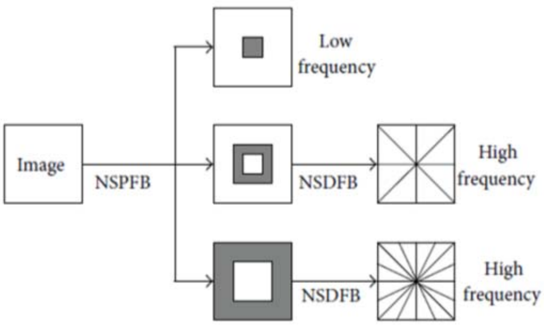

Fig. 9 NSCT decomposed schematic diagram

NSP stages ensures the multi-scale property by using two channel non sub-sampled filter bank [6].one low frequency image and one high frequency image can be produced at can be produced at each NSP decomposition level. The subsequent NSP decomposition stages are carried out to decompose the low-frequency component available iteratively to capture the singularities in the image. As a result, NSP can result in k+1 sub-images, which consists of one low- and k high-frequency images having the same size as the source image where k denotes the number of decomposition levels.

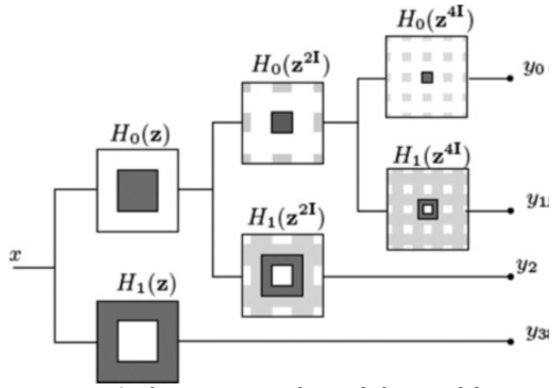

Fig. 10 Three stage non sub-sampled pyramid decomposition

NSDFB is two-channel non-sub sampled filter banks which are constructed by combining the directional fan filter banks. NSDFB allows the direction decomposition with l stages in high-frequency images from NSP at each scale and produces 2^l directional sub-images with the same size as the source image. Therefore, the NSDFB offers the NSCT with the multi-direction property and provides us with more precise directional details information [12].

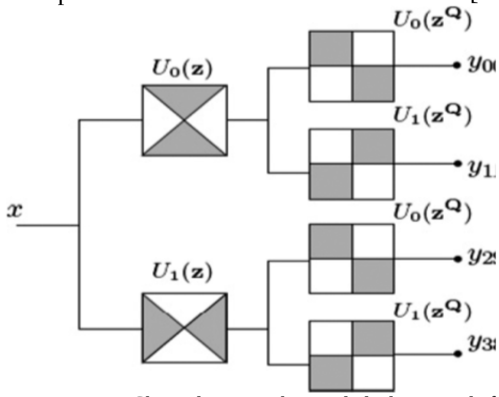

Fig. 11 Four Channel non sub-sampled directional filter bank decomposition

J. Srikanth et al. [1] presented the wavelet transforms of the input images are properly pooled the new image is achieved by taking the inverse wavelet transform of the fused wavelet coefficients. The suggestion is to progress the image content by fusing images like computer tomography (CT) and magnetic resonance imaging (MRI) images so as to recommend more information to the doctor and clinical treatment planning system. They demonstrate the application of wavelet transformation to multi- modality medical image fusion. This work covers the selection of wavelet function, the use of wavelet based fusion algorithms on medical image fusion of CT and MRI, implementation of fusion rules and the fusion image quality evaluation. The fusion performance is estimated on the basis of the root mean square error.

Kanaka Raju Penmetsa et al. [2] proposed a DT-CWT method which is used in de-noising of colour images. CDWT is a form of DWT in which complex coefficients (real and imaginary parts) are generated by using a dual tree of wavelet transform. The experiments on an amount of customary colour images carried out to approximate performance of the proposed method. Outcome shows that the DT-CWT method is better than that of DWT method in terms of image visual eminence.

Pavithra C et al. [3] presented a method for fusing two dimensional multi-resolution 2-D images using wavelet transform under the combine gradient and smoothness criterion. The usefulness of the method has been illustrated using various experimental image pairs such as the multi-focus images, multi-sensor satellite image and CT and MR images of cross-section of human brain. The results of the proposed method have been compared with that of some widely used wavelet transform based image fusion methods both qualitatively and quantitatively. An experimental result expose that the proposed method produces better fused image than that by the latter. The use of mutually gradient and relative smoothness criterion ensures two fold effects. While the gradient criterion ensure that edges in the images are included in the fused algorithm, the relative smoothness criterion ensures that the areas of uniform intensity are also incorporated in the fused image thus the effect of noise is minimized. It should be noted that the proposed algorithm is domain independent.

Hasan Demirel et al. [4] Complex Wavelet Transform (CWT) is used in image processing. CWT of an image produces two complex-valued low-frequency sub-band images and six complex valued highfrequency sub-band images. DT-CWT decomposes original image into different sub-band images. Then high frequency sub-band images and original low frequency image are undergoes the interpolation. These two real-valued images are used as the real and imaginary components of the interpolated complex LL image, respectively, for the IDT-CWT operation. This technique does not interpolate the original image but also interpolates high frequency sub-band image resulting from DT-CWT. The final output image is high resolution of the original input image. Quality and PSNR of the super resolved image is also improves in this method. There are some problems with wavelet domain also, it introduces artifacts like aliasing, any wavelet coefficient processing upsets the delicate balance between forward and inverse transform leading to some artifacts in the images. Also constructs lack of directional selectivity substantially make difficult modelling and processing of geometric image features like ridges and edges. One resolution to all these problems in Complex Wavelet Transform (CWT). CWT is only somewhat like magnitude or phase, shift invariant and free from aliasing.

Prabhdeep Kaur [5] In discrete wavelet change (DWT) decomposition, the filters are particularly developed to ensure that successive layers of the chart just contain details which are not presently accessible at the preceding levels. The DWT decomposition works on the cascade of special low pass and high-pass filters and a subsampling operation. The components from 2D-DWT are four photographs having measurement add up to half how big is the original picture.

Mandeep Kaur [6] has studied that the aim of vision fusion would be to merge information from many images of the exact view to be able to deliver only the useful information. The discrete cosine transform based types of vision fusion are considerably better and time-saving in real-time systems using discrete cosine transform based values of unmoving image or video

Desale et al. [7] vision Fusion is an activity of combining the related information from a set of images, right into a single vision, where in the resultant fused vision may well be more informative and complete than some of the input images. This paper discusses the Formulation, Process Flow Diagrams and algorithms of PCA (principal Component Analysis), DCT (Discrete Cosine Transform) and DWT (Discrete Wavelet Transform) based vision fusion techniques. The PCA & DCT are conventional fusion techniques with many drawbacks. Two algorithms centered on DWT are proposed, they're, pixel averaging & maximum pixel replacement approach.

TABLE I
COMPARISON OF DIFFERENT FUSION TECHNIQUES

Approaches	Merits	Demerits
Wavelet Transform	It reduces the storage cost	Not able to maintain edge information efficiently
Second generation Wavelet Transforms	It has multi scale dimensionality	I has poor directionality
wavelet transform using gradient and smoothness criterion	It is able to retain the edge information also minimize the noise	It is domain independent
Complex Wavelet Transform (CWT)	magnitude or phase, shift invariant and free from aliasing	Most expensive and computational intensive
DT-CWT method	Image visual eminence is better	Has limited directionality
DWT based technique	More accurate clinical information for medical diagnosis & evaluation	Poor directionality, Shift sensitivity, Absence of phase information.
DCT based technique	Simple, fast & energy efficient multifocus image fusion scheme	It consumes more time than wavelet based method as two diff multiscale decomposition process are applied.
PCA	Superior quality of image is available	Greater computational requirements.
Contourlet Transform directional windows	Captures directional information of natural images	It need to find the image fusion techniques for better results
NSCT with local energy match	Uses directional vector from high frequency sub bands to fuse low frequency sub bands	Not able to utilize prominent information present in the low frequency efficiently ,poor quality

1) Normalized Mutual Information: Mutual information (MI) is a quantitative measure of the mutual dependence of two variables. It usually shows measurement of the information shared by two images. Mathematically, MI between two discrete random variables U and V is defined as,

$$MI(U,V) = \sum_{u\in U}\sum_{v\in V} p(u,v)log_2\frac{p(u,v)}{p(u)p(v)} \quad (10)$$

where $p(u, v)$ is the joint probability distribution function U and V. Based on the above definition, the quality of the fused
image with respect to input images and can be expressed as

$$QMI = 2\left[\frac{MI(A,F)}{H(A)+H(F)} + \frac{MI(B,F)}{H(B)+H(F)}\right] \quad (11)$$

2) Structural Similarity based Metric: Structural similarity (SSIM) is designed by modeling any image distortion as the combination of loss of correlation, radiometric and contrast distortion. Mathematically, SSIM between two variables U and V is defined as

$$SSIM(U,V) = \frac{\sigma uv}{\sigma u\sigma v}\ \frac{2\mu u\ \mu v}{\mu u^2\mu v^2}\ \frac{2\sigma u\ \sigma v}{\sigma u^2\sigma v^2} \quad (12)$$

3) *Edge Based Similarity Measure*: The edge based similarity
measure gives the similarity between the edges transferred in
the fusion process. Mathematically, $Q^{\frac{AB}{F}}$ is defined as,

$$Q^{\frac{AB}{F}} = \frac{\sum_{i=1}^{M}\sum_{i=1}^{N}[Q_{i,j}^{AF}w_{i,j}^{x}+Q_{i,j}^{BF}w_{i,j}^{y}]}{\sum_{i=1}^{M}\sum_{i=1}^{N}[w_{i,j}^{x}+w_{i,j}^{y}]} \quad (13)$$

III. CONCLUSION

Multimodal medical image fusion plays an important role in clinical applications. This is a major source for the doctors to diagnose the diseases. Whatsoever the medical imaging has its own kinds of imaging techniques like X-ray, computed tomography (CT), magnetic resonance imaging (MRI). However the characteristics and results of each of these medical imaging techniques are unique. For instance, X-ray and CT can provide images as dense like structure with which the physiological changes could not be detected whereas in MRI images even the soft pathological tissues can be visualized better. As a result the anatomical and functional medical images are needed to be combined for better visualization and for accurate diagnosis.

By conducting the review it's been unearthed that the all of the existing literature has neglected many issues. As all of the existing methods are based upon transform domain therefore it may results in certain color artifacts which may decrease the performance of the transform based vision fusion methods. It is also unearthed that the problem of the uneven illuminate has been neglected in the absolute most of existing focus on fusion. A lot of the existing work has centered on gray scale images little work is performed for color images. To acquire the crucial features or attributes of the images of common features image fusion is widely used technology. The wavelet transform is one of the most efficient approaches to extract the features by the transformation and decomposition process but this method is not efficient to retain the edge information. But the real challenge is to obtain a visually enhanced image through fusion process. To serve this purpose the multimodal medical image fusion is an effective way to provide solution to generate information from medical image fusion. In this paper, a novel and effective image fusion framework based on NSCT is proposed. The potential advantages include (1) NSCT is more suitable for image fusion because of its advantages such as multi resolution, multi direction, and shift-invariance; (2) a new couple of fusion rules based on phase congruency and Directive contrast are used to preserve more useful information in the fused image to improve the quality of the fused images and overcome the limitations of the traditional fusion rules; and (3) the proposed method can provide a better performance than the current fusion methods whatever the source images are clean or noisy. This fusion technique not only provides accurate diagnosis and analysis but also helps in reducing the storage cost by reducing storage to a single fused images.

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