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# A Literature Review on Image Fusion Techniques for Biomedical Images

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**ABSTRACT**

The requirement for image fusion in image processing applications is expanding primarily owing to the increased number and variety of image acquisition strategies. Image fusion is elucidated as the procedure of consolidating significant information from several sensors utilizing numerical techniques in order to create a solitary image that will be more inclusive and thus, provides information which will be more useful for medical practitioners. This paper provides a literature review on various image fusion techniques such as Discrete Wavelet Transform(DWT), Stationary Wavelet Transform(SWT), Non Subsampled Contourlet Transform(NSCT), Shearlet Transform, framelet transform, wavelet transform etc.
**Keywords**: Discrete Wavelet Transform, Stationary Wavelet Transform, Non Subsampled Contourlet Transform, Shearlet Transform, framelet transform, wavelet transform etc.

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## INTRODUCTION

Image fusion can be characterized as the synergistic utilization of knowledge from distinctive sources to assist in overall apprehension of an event. Image fusion alludes to the procedure of joining two or more images into a single solitary image, that can coordinate the data contained within the individual images. The outcome is an image that has a higher data content compared to each of the individual images. Multi-modal image fusion, is a simple passageway for physicians to perceive the lesion to analyze images of distinctive modalities. Different medical imaging modalities such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI),Positron Emission Tomography (PET), Single Photon Emission Tomography (SPECT)etc provides different information about the human body which is important in diagnosing diseases. However, these modalities are not capable of providing complete information either by observational constraints. [1]For example CT provides information regarding dense structures like bones while information regarding soft tissues can be obtained by using MRI while PET reveals the cellular level metabolic changes that occurs in an organ or a tissue. Hence the objective of the image fusion is to compute the content at every pixel position in the input images and sustain the data from that image which represents the genuine scene or upgrades the potency of the fused image for an accurate application.

[2]In the past few decades, various algorithms had been proposed to perform image fusion at pixel , decision and feature level. [3] Research is now concentrated on performing image fusion at pixel level because pixel level algorithms are computationally efficient and easy to implement. Image fusion techniques are broadly classified into multi scale decomposition based image fusion and non multi scale decomposition based image fusion. Some of the multi scale decomposition methods are- Pyramid transform, wavelet transform, curvelet transform and contourlet transform while non multi scale transform decomposition methods includes average, non linear and estimation theory based methods. Multi scale decomposition methodologies performs better than non multi scale decomposition strategies. The quality of the fused image is analyzed by utilizing suitable objective quality metrics such as Root Mean Square Error(RMSE), Entropy, Standard Deviation(SD), Mutual Information(MI), Peak Signal to Noise Ratio(PSNR), Correlation Coefficient(CC) etc.

The rest of the paper is organized as follows. Section II provides a brief description about various image fusion techniques and conclusion is provided in section III.

## PRIOR WORK

The key for successful image fusion lies in constructing a good dictionary in sparsity-based models. [4] Minjae Kim et al has put forward an effective dictionary learning methodology based on a joint patch clustering for multi modal images. To construct an efficient dictionary, all patches from source images are clustered together which includes their structural similarities. To develop a compact dictionary, a few principal components that describes each of the joint patch clusters will be chosen and merged to develop a complete dictionary. Sparse representation will represent an image signal as a linear amalgamation of atoms in an over complete dictionary. Initially, the source images are decomposed into low and high frequency components to form the sparse model from the high frequency components. A Gaussian smoothed version of the input image is considered as the low frequency component while high frequency components are determined by subtracting the low frequency component from the source image. The sparse coefficients are then selected by utilizing orthogonal matching pursuit algorithm. Experimental outcomes illustrates that the proposed methodology performs better than conventional multi scale transforms and sparse representation based methodologies. The proposed strategy eliminates the ringing artifacts which is caused by smoothed low frequency component.

Score fusion is a very proficient fusion approach and weighted score fusion is the most superior score fusion approach. Setting the weights properly is the important key factor of weighted score fusion To automatically set proper weights is the most important key of weighted score fusion. [5] In this paper, Yong Xu et al has put forward a novel framework to design an adaptive weighted fusion approach which determines their optimal weights on their own. The proposed strategy assigns weights to different types of data sources and doesn’t take particular test sample into consideration. Numerous experiments were conducted on PolyU multispectral palm print dataset, Heterogeneous Face Biometrics (HFB) and 2D plus 3D palm print dataset. Experimental outcomes demonstrates that the proposed approach outperforms existing state-of –the-art score fusion approaches.

Mankar.R et al has put forward a new multi modality medical image fusion methodology based on discrete Non Subsampled Contourlet transform and pixel level fusion principle.[6]The main objective of the proposed methodology is to minimize the error between input and the fused image. Regarding the medical diagnosis, the information along the edges is more important than other information. Thus, it becomes essential to conserve the information along the edges. To accomplish this, medical fusion methodology based on discrete contourlet transformation has been proposed which provides more details about edges. This methodology decomposes the image into finer and coarser details and finest details with different resolution in different orientation. Averaging, Gabor filter bank and Gradient fusion algorithm has been applied for low and high frequency coefficients. To obtain the fused output, inverse NS Contourlet transformation has been applied. Visual and quantitative evaluation illustrates the effectiveness of the proposed methodology.

Medical image fusion amalgamates functional and anatomical information from different imaging modalities such as Computer Tomography (CT) and Magnetic Resonance Image (MRI). [7]Biswas, B et al has put forward a spine medical image fusion methodology in which CT and MR of the spine provides integral data that aids the diagnostic and therapeutic resolution. The author has put forward a spine medical image fusion using wiener filter (WF) in shearlet domain. Initially, shearlet Transform determines the shearlet sub bands followed by applying suitable fusion strategy for low and high frequency shearlet sub bands. The fused image can be reconstructed by applying inverse shearlet transform. By evaluating the proposed algorithm using certain quality indexes it is obvious that the spine fusion algorithm outperforms the existing image fusion methods.

Schemic stroke is a condition which causes demise of brain cells owing to absence of blood supply . Because of finite academic investigations of ischemic stroke detection, the success rate to discover stroke during the initial period is low using only CT image. To overcome the above drawback, CT and MRI images are fused to produce a composite image which provides more information than any of the input images.[8] In this paper Mirajkar P.R et al has put forward a new image fusion methodology utilizing wavelet transform. The proposed algorithm comprises of four phases. The first phase involves preprocessing of CT and DW-MRI images. Determining equivalent CT image for input MRI image is done in second phase. Third phase incorporates image registration and fusion of CT and MRI image. Finally, Segmentation of stroke lesion from fused image is performed. The assessment of proposed methodology is processed utilizing quality metrics such as Peak Signal to Noise Ratio (PSNR) and Root Mean Square Error (RMSE).

In recent years numerous imaging modalities are utilized in several applications such as surveillance, medical imaging and machine vision. In multi-sensor frameworks there is a requirement for image fusion techniques to adequately combine the information from dissimilar image sensors into a solitary composite image which empowers a good comprehension of the scene. The existing image fusion algorithms utilize either the mean or choose-max fusion rule. Choose max fusion rule misshapes background information while the mean rule obscures the edges. To overcome the above drawback, Egfin Nirmala, D et al has replaced maximum or mean fusion rule by a soft computing technique which makes intelligent decisions to enhance the accuracy of the fusion process. Decomposition is done by utilizing Non Sub-sampled Contourlet Transform (NSCT). NSCT is employed since it captures the intrinsic geometric structures in an image in a more effective manner than existing image fusion algorithms. Subjective and quantitative analysis reveals that the proposed methodology provides clear edge information than multi-resolution methods such as DWT.

In this paper, Paramanandham, N et al has proposed a novel multi focus image fusion method by combining Discrete Wavelet Transform and Stationary Wavelet Transform. [10] Initially, the source images are decomposed by utilizing wavelet transform and the coefficients are fused using suitable fusion rules. An informative fused image is obtained by applying suitable inverse wavelet transforms. The proposed algorithm is evaluated by employing suitable quality metrics parameters such as RMSE, PSNR, SF and Entropy. The experimental results demonstrates that the proposed fusion approach is effective from both visual and quantitative inspection.

Bhateja, V. et al has put forward a two-stage multimodal fusion framework utilizing the cascaded combination of stationary wavelet transform (SWT) and non sub-sampled Contourlet transform (NSCT). [11]The significant advantage of using a cascaded combination of SWT and NSCT is to improve certain features such as -shift invariance, directionality, and phase information in the fused image. The first stage utilizes a principal component analysis algorithm in SWT domain to reduce the redundancy. The second stage involves application of Maximum fusion rule to NSCT domain to improve the contrast of the diagnostic features. Quantitative analysis demonstrates the advantages of the proposed methodology. The cascaded combination approach is then compared with are also state-of-the-art fusion approaches which reveals the superiority of the cascaded combination.

Multimodal medical image fusion plays a critical role in medical diagnosis and treatment. Most commonly used transform domain based image fusion techniques like DWT, CVT, CT, NCST experiences major ill effects such as spatial inconsistency and high complexity. Guided filter based spatial domain image fusion techniques also suffers from contrast reduction and halo artifacts. [12] In this paper, Pritika et al has modified the existing guided filter based image fusion scheme by utilizing Gaussian decomposition with local average energy for base layer and average gradient based saliency for detail layer. Quantitative analysis illustrates that the proposed algorithm is more effective in preserving contrast and fine details than the existing guided filter based and DWT based fusion strategies.

Po-Whei Huang et al has put forward PET and MR brain image fusion method utilizing wavelet transform. [13] The proposed technique can produce very good fusion result by conforming the anatomical structural data in the gray matter (GM) zone, and then fixing the spectral information in the white matter (WM) zone after the wavelet deterioration and gray-level fusion. The author has utilized normal axial, normal coronal, and Alzheimer's disease brain images as the three datasets for testing and Correlation. Experimental analysis shows that the performance of the proposed algorithm method is superior to IHS+RIM fusion method in terms of spectral discrepancy (SD) and average gradient (AG). On perception the author has observed that there is a critical color difference between high- and low-activity regions in the PET image. The high-activity region will be in red or yellow colors while the low-activity region will be in blue color in a PET image. Hence the author has utilized the information about the "hue angle" to differentiate high-activity region from low-activity region. The proposed methodology is distinct from the DWT fusion due to the following reasons. The proposed methodology performs wavelet decomposition with various levels for low- and high-activity regions in the PET and MR brain images. Also, a novel adjustment for the pixel intensity in the non- WM area of high-activity region brings more anatomical structural information into the final color fused image.

Das et al has put forward a novel approach to the multimodal medical image fusion which utilizes multi scale geometric investigation of the non subsampled contourlet transform and fuzzy-adaptive reduced pulse-coupled neural network (RPCNN). [14] To overcome the downsides of the traditional MIF schemes, the author has exploited the advantages of the NSCT, RPCNN, and fuzzy logic. The linking strengths of the RPCNNs' neurons are adaptively set by representing them as the fuzzy membership values which results in a high quality fused image. The author has proposed this technique to adaptively set the value of $\beta$ by estimating the importance of each coefficient in the corresponding image. If a coefficient's "local average energy (LAE)" is large or if its "local information entropy (LIE)" is large, then the coefficient has more importance in the image. The experimental consequences illustrates that the proposed approach can preserve more useful information in the fused image with higher spatial resolution. The author has compared the proposed methodology with state-of-the art MIF techniques . Experimental outcomes demonstrates that the proposed scheme is free from the common shortcomings of the state-of-the art MIF techniques such as contrast reduction, loss of image fine details, and unwanted image degradations, etc. Visual and Quantitative evaluations demonstrates the advantages of the proposed methodology compared to the existing techniques. The author has concluded by stating that the proposed methodology can be extended by using different fusion rules or by using new methodologies to compute the parameters of the neurons of the PCNN.

Shutao Li has put forward a new methodology which depends on two scale decomposition of an image utilizing a guided filter. The two scale decomposition comprises of 2 layers- base layers and a detail layer. [15]The base layer contains substantial scale variations of intensities while the detail layer contains every small scale detail. Weighted average technique has been proposed to make use of spatial consistency of base and detail layers. In addition, this technique introduces a fast two scale fusion method. Guided filtering technique has been utilized as a local filtering method which is a edge preserving filter. The computation time of guided filter is autonomic of filter size. Besides guided filter makes full use of strong interrelationships between neighbouring pixels. The author terminates that this methodology can be utilized expertly for image registration that preserves the original and complementary data of individual source images.

Gaurav Bhatnagar et al has put forward a novel framework for medical image fusion based on framelet transform.[16]PCA/ICA often produces undesirable side effects like block artifacts, reduced contrast etc. which frequently leads to undesirable results. In this paper an attempt has been made to rectify the downside of multi-resolution transform in medical image fusion. For this purpose, framelet transform has been used in the proposed framework. The main idea behind the proposed technique is to disintegrate the source images by the framelet transform. The framelet transform has FIR perfect reconstruction filter banks which renovates reconstructed signals with almost no or minimal error. The proposed technique produces shift invariance behavior and lesser artifacts when compared with non-oversampled filter banks utilized in the wavelet related transform. The efficiency of the proposed framework is analyzed by conducting various experiments on medical images. The major advantages of framelet transform are symmetry, simple sampling and large vanishing moments . Also, smoother scaling and more informative detail coefficients are generated when compared to other multi resolution methods. Additionally, two clinical examples of the persons affected with Alzheimer and tumor have also been conducted for more elaborated performance comparison analysis. Statistical and numerical analysis involves huge computation using floating-point arithmetic, and these methods are time and memory consuming.

Gaurav Bhatnagar et al has presented a fusion frame work based on non- sub sampled contourlet transform. [17] In this methodology, the source images are initially disintegrated utilizing NSCT technique followed by fusion of low and high frequency coefficients. In this paper, two different fusion rules which utilizes phase congruency and directive contrast rule to fuse low and high frequency components. Finally the fused image is produced by the employing inverse NSCT technique. From experimental results, it is inferred that the proposed methodology produces better results from both visual and quantitative view. The outstanding benefit of phase congruency is that the low frequency coefficients produces a contrast and brightness invariant representation which can be finally combined and contrasted.

## CONCLUSION

In this paper, various image fusion techniques has been reviewed from the most recent published research work.

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