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Fusion of Medical Image by using STSVD - A Survey

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Abstract— Medical Image fusion is a process of combining multiple images of same or different imaging modalities into single image to increase the information content in the image and also to reduce the randomness and redundancy which will be used for clinical applicability. The multi-modal fusion of medical images has shown notable achievements in clinical accuracy. This survey provides listing of different imaging modalities, fusion algorithms, performance metrics and the proposed method. A new technique called Singular Value Decomposition (SVD) method on Shearlet Transform (ST) is proposed to improve the information content of an image by fusing images like Positron Emission Tomography (PET) and Magnetic Resonance Imaging (MRI) images. Initially source image is transformed into shearlet-image by using ST. Then SVD model is used in low-pass sub-band and modified selected sub-bands as per their local characteristics. The compositions of different high-pass sub-band coefficients are processed by ST decomposition. Then the high and the low sub-band are fused. Finally, Inverse Shearlet Transform (IST) is used to reconstruct the fused image.

Keywords— Shearlet Transform, Singular Value Decomposition, Medical Image Fusion, Positron Emission Tomography, Inverse Shearlet Transform, Mutual Information, Edge Indexing.

I. INTRODUCTION

Image fusion is important in medical studies for diagnosis of several diseases. It also used in image analysis and historical documentation. The purpose of image fusion is to combine information from two or more images into single image which contains more information than the source images. There is a rapid growth in this field in recent years which leads to development of many fusion techniques. There exist many medical imaging modalities that are used as the primary inputs to the studies of medical image fusion. The selection of imaging modality depends on clinical requirements like the organs which undergo for study. Practically it is not possible to get all the details from single image for clinical accuracy.

The aim of this review is to provide a collective view of different modalities, image fusion techniques and how the proposed method is better than the existing methods. Figure 1 shows the three major focused areas in medical image fusion: (a) identification, improvement and development of imaging modalities, (b) development of different techniques, and (c) Studying of human organs of interest. Recently, lots of image fusion techniques have been developed such as Wavelet Transform (WT), Principal Component Analysis (PCA), and Non-Subsampled Contourlet Transform (NSCT) to fuse the images like MRI, PET and Computed Tomography (CT). There are two types of fusion methods, spatial domain method and transform domain method.

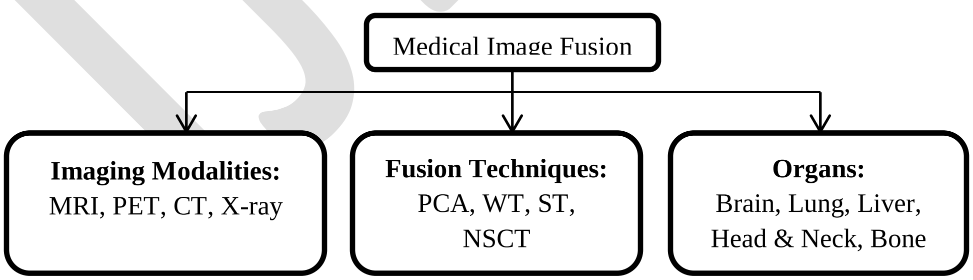

Figure 1. Structure of Medical Image Fusion.

The fusion method averaging principal component analysis comes under spatial domain approaches. But it suffers from reduced sharpness and contrast. The pixel-based methods, cause inaccurate measurement of sharpness and also contains noise which decreases the performance. The use of region based methods solves the noise problems. The limitation is that the artifacts may appear at the boundaries which greatly reduce the quality of the fused image.

Spatial distortion can be handled by using frequency domain approaches. WT has evolved as a great multi-resolution system with many characteristic such as time-frequency localization, multi-scale characteristic and sparse representation of function [4]. But it also has limitation that the images containing higher dimension singularity, cannot reach the optimal sparse representation [20]. In order to resolve the limitation, WT has been attached with multi-scale geometric analysis theory. This has been successfully developed and materialized as a series of new multi-scale geometric transform method, for example, ridgelet [20, 23], curvelet [20], and contourlet. In recent times, many authors have developed fundamental composition of ST through the affine system that offers excellent capability in analysis and synthesis.

SVD is a popular method for feature extraction and is used for image fusion. SVD-based fusion is used for image registration and is widely used in data compression. The new image fusion algorithm is proposed by combining ST and SVD techniques.

The paper is organized as follows: Section II gives a brief description of multiple imaging modalities, section III briefs about different fusion techniques, section IV Contains Performance metrics, proposed method is described in section V , section VI briefs the analysis of results and finally conclusion is discussed in section VII.

II. IMAGING MODALITIES USED IN IMAGE FUSION.

A. Magnetic Resonance Imaging (MRI)

MRI is one of the mostly commonly used imaging modality in medical studies. It is used to get information about soft tissues of the body. Image segmentation is mostly used to identify the objects and interested regions of the image. The advantage of MRI is that it does not involve any exposure to radiation, so it is very safe for pregnant women and babies [4, 24]. The disadvantage is that it is very noisy and difficult in accessing the organs that involve in movement and will not show bone or calcium which results in not finding many diseases [17].

B. Positron Emission Tomography (PET)

PET provides information of blood flow in the body. Its major application is diagnosis of diseases of brain and some other applications such as image segmentation and integration, breast and lung cancer detection. One of the main challenges of PET is its resolution limits. The limitations can be reduced by performing image reconstruction with finite resolution effects and improved detector design [17, 24]. The advantage is that the small movements do not destruct the scan and it is very accurate in differentiating between malignant and cell growth [3].

C. Computed Tomography (CT)

CT provides more information about of bone tissues and less about soft tissues. It is considered as prime modality in several applications such as diagnosis of head and neck cancer, lung cancer treatment, detection in tumor, bone cancer treatment and cervical cancer treatment [17, 4]. The advantages of this scan are high resolution of image and short scan time.

D. X-ray

X-rays are electromagnetic radiations which help in identifying cracks, injury, abnormal bones and bone cancers. The advantage is that they are cheaper than other modalities. The disadvantage is that they do not give detailed images and also exposure to X-rays for long period can damage the tissues and also it cannot be used for soft tissues.

III. MEDICAL IMAGE FUSION TECHNIQUES

A. Wavelet Transform (WT)

The primary concept with this is to extract detailed information from one image and give it into another. The representation of wavelet consists of low-pass band and high-pass band at each step. It is invertible and non-redundant transform. Some of the WT are Haar Wavelet Transform [25], Discrete Wavelet Transform [18, 15].The features of Haar transform includes fast for implementation and used in signal and image compression. There are several applications of this such as super resolution, medical image pseudo coloring, feature level image fusion, segmentation, medical diagnosis and color visualization.

B. Non-Subsampled Contourlet Transform (NSCT)

NSCT is based on the theory of Contourlet Transform [13]. It is of two stages, includes Non-Subsampled Laplacian Pyramid (NLP) is used to capture the point discontinuities and Non-subsampled Directional Filter Bank (NDFB) is used to form those into linear structures [22, 23]. There are two channel non-subsampled filter bank, one is low-frequency image and other is high-frequency image which can be produced at each decomposition level. The subsequent NSP decomposition is applied on low-frequency component iteratively to get the singularities present in the image. So the NSP results in sub-images, which consists of low and high-frequency images of same size as the source image. NDFB allows the direction decomposition with stages in high-frequency images from NSP at each scale and it produces directional sub-images with the same size as of source image. Therefore, the NDFB offers NSCT with the property multi-direction and provides with more precise directional details information.

C. Principal Component Analysis (PCA)

It is a vector space transform used to reduce multi-dimensional data sets to lower dimensions for analysis. The algorithm involves the following steps: (i) From the input image matrix generate the column vectors; (ii) For the 2 column vectors formed in previous step calculate the covariance matrix; (iii) The diagonal elements of 2x2 covariance vector should contain variance of each column vector with itself; (iv) Determine the Eigen vectors and Eigen values of covariance vector and then obtain the Eigen vector corresponding to larger Eigen values; (v) Compute the normalized components from the Eigen vectors obtained in the previous step; (vi) Sum of two scaled matrices calculated in previous step will be the fused image [20].

D. Shearlet Transform (ST)

The ST solves multi-variate problem by efficiently encoding anisotropic features. It is natural extension of wavelets to make suitable for the multi-variate functions. There are two primary steps of ST, multi-scale decomposition and directional localization. The drawback is that as the frequency support of shearlet aligns along axis as it increases the shearing parameter leads to infinity. This is a serious problem when analyzing the functions if the functions are concentrated around the axis. To solve this problem the frequency domain splits into low-frequency part and two conical regions. The cone adapted discrete shearlet system has three parts, each of them corresponds to one of the frequency domains and finally for the low-frequency part the scaling function applied.

IV. PERFORMANCE METRICS

A. Mutual Information (MI)

MI determines how much information the fused image gives from the source images [6]. As higher the value of MI the fused image contains good quantity of information presented from the original images. It is calculated as, by adding the MI between the fused image and each of the source images.

$$MI=I(I_1,I_f)+I(I_2,I_f)$$

B. Edge Indexing

Edge Indexing ($Q^{AB/F}$) determines how much edge information is transferred to fused image from the source images. As higher the value of edge indexing the quantity of information transferred is higher from source images to the fused image.

V. THE PROPOSED FUSION ALGORITHM

A. Concept of Singular Value Decomposition

Singular Value Decomposition (SVD) is an efficient algebraic method used to extract important features from the image [7]. It is decomposed into a singular value matrix containing only a few non-zero values. Singular value represents several image descriptions, rotation and scaling invariability, for instance feature stability. SVD of an m×n matrix A is decomposed into three matrices specified by

$$A = U_A \Sigma_A V_A^T$$

Where U_A is m × m matrix known as *left singular vectors*, V_A^T is n × n matrix known as *right singular vectors*, and Σ_A =diag ($\sigma 1$, $\sigma 2$, · · · , σn) is m× n diagonal matrix called as the *singular values*. The singular vectors arranged in a decreasing order of singular values, with the highest singular value existing in upper left corner of the Σ_A matrix, specifically, ($\sigma 1 \geq \sigma 2 \geq \ldots\ldots\ldots \geq \sigma q \geq 0$).

B. Proposed method

A new medical image fusion algorithm is developed to share the advantages of Shearlet Transform. This fusion algorithm is named as Shearlet Transform with Singular Value Decomposition (STSVD). There are two parts in the proposed fusion method. First part is the low frequency coefficients of the original image which is manipulated by using SVD with *Maximization* method. Second part is the high frequency coefficients manipulated by using adaptive parameter which is derived from high-pass sub-bands of same and the different level. The schematic diagram of the proposed algorithm is shown in Figure 2.

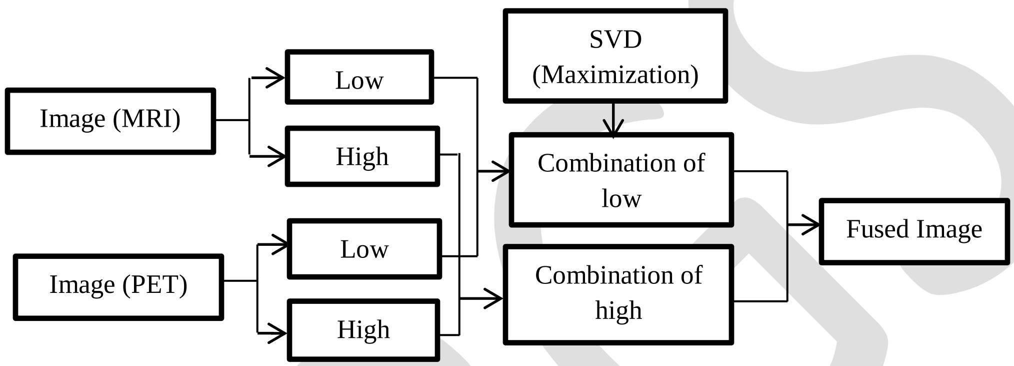

Figure 2.Schematic diagram of the STSVD based fusion algorithm.

VI. ANALYSIS OF RESULTS

In the field of medical image diagnosis there are several technological and it also faces many challenges. The increase of imaging technologies results in improved imaging accuracies. However, each imaging modality has its own limitations, which enforces to explore the new imaging technologies. The main challenge in applying the image fusion algorithms is that it should be safe for medical diagnosis and should result in better clinical outcome. The right combination of different imaging modalities, feature extraction, feature processing and decision fusion algorithms which targets a specific clinical problem. The necessary for improving the image quality results from signal noise and the physical limitations of the imaging modalities and another area of interest is processing speed.

Wavelet transform [10, 18] is one of the most commonly used image fusion technique. It has many characteristics such as multi-scale, time and frequency localization and representation of sparse function. Because of its multiple characteristics it has developed as great multi-resolution system.

In [1] the author proposed Redundant Discrete Wavelet Transform (RDWT) to overcome the problem of the DWT that is shift variance. But is mostly used in different signal processing and it is not well researched in medical image fusion. In [3] the multi-wavelet transform has applied on PET and CT images which have many properties like orthogonality, short support, symmetry and smoothness are very important for image processing and analysis. There is no strict division of low and high-pass in multi-wavelet filter banks. The major disadvantage of DWT [11, 12, 14, 15, and 26] is that it gives more number of coefficients in all directions of edges of image. So for reconstruction of exact edges these many coefficients are required, but it is not possible form DWT to handle such long curved edges. To solve this limitation it is attached with other geometric analysis theory. So from this there were several methods has been developed such as curvelet, ridgelet and contourlet.

So in [4, 21] the new approaches like curvelet transform and ridgelet transform has come in to existence which handles curvilinear and long linear singularities. In this transform instead of DWT, the Additive Wavelet Transform (AWT) is used to decompose the image. After decomposition into different sub-bands they are called as approximation plane and detail plane and each detail plane is divided into small tiles. On each tile the ridgelet transform is applied to represent the image edges after applying the edges look like small straight lines. In this way the ridgelet transform is efficient in detecting curved edges.

In [8, 13 and 22], the NSCT has applied on MRI and CT images. To perform this phase congruency and directive contrast are used as fusion rules for low and high frequency coefficients. The phase congruency provides brightness invariant and contrast representation of the low-frequency coefficients and directive contrast is used to get frequency coefficients from clear parts of the high frequency. The combination of these two preserves the source image details and improves the quality of the fused image.

In [20, 27] the PCA and Dual Tree Complex Wavelet Transform (DTCWT) were applied on CT and MRI images. In comparison to wavelet transform, the DTCWT has high directional selectivity and is also a shift invariant. The directional selectivity improvement represents the information across boundaries of the image and it also provides phase information. For selectively combining the complex wavelet coefficients the PCA is used as a fusion rule which removes redundant information present in DTCWT.

Recently the fundamental composition of ST [5, 9 and 28] has been developed by many authors through the affine system which is excellent in synthesis and analysis. The ST is mainly used to encode the anisotropic features which are in multi-variate problem.

SVD [2, 7] is popularly used for feature extraction and used for fusion of image. It is also used for image registration. The SVD based fusion is used for super resolution problems and it also transforms number of correlated variables into multiple orthogonal variables. It is mostly used in data compression [7]. So we propose a new medical image fusion method to add the advantages of ST to the image fusion technique like inter-scale sub-band dependencies. The fusion algorithm is named as STSVD.

VII. CONCLUSION

In this paper various image fusion techniques has been reviewed from different published papers where each of them has its own limitations. So we propose a new method STSVD which has more advantages than other methods. The goal of this is to preserve the information from the source images and the main advantage is that it is capable of retaining the optimal composition of colors of the image. This results in improving the detection of accuracy of image in smooth regions.

REFERENCES:

[1]. Richa Singh, Mayank Vatsa, Afzel Noore, "Multimodal Medical Image Fusion using Redundant Discrete Wavelet Transform", IEEE-Seventh International Conference on Advances in Pattern Recognition, pp.232-235, 2009.

[2]. D.W.Repperger, A.R.Pinkus, K.A. Farris, R.G.Roberts, R.D.Sorkin, "Investigation of image fusion procedures using optimal registration and SVD algorithms", in: Proceedings of the IEEE- National Aerospace and Electronics Conference, pp. 231 235, 2009.

[3]. Yuhui Liu, Jinzhu Yang, Jinshan Sun, "PET/CT Medical Image Fusion Algorithm Based on Multiwavelet Transform", IEEE, pp.264-268, 2010.

[4]. F. Ali, I. El-Dokany, A. Saad, F. El-Samie, "A curvelet transform approach for the fusion of MR and CT images", Journal of Modern Optics, vol.57, pp. 273-286, 2010.

[5]. Wang-Q Lim, "The Discrete Shearlet Transform: A New Directional Transform and Compactly Supported Shearlet Frames", IEEE Transactions On Image Processing, vol. 19, no. 5, may 2010.

[6]. MA. Mohamed and R.M EI-Den, "Implementation of Image Fusion Techniques for Multi-Focus Images Using FPGA", 28th National Radio Science Conference, April 26-28, 2011.

[7]. H.Nasir, etal. "Singular value decomposition based fusion for super resolution image reconstruction", Signal Processing-Image Communication, 2011.

[8]. T.J. Li, Y.Y. Wang, "Biological image fusion using a NSCT based variable weight method", Information Fusion, vol. no.12, pp. 85-92, 2011.

[9]. L. Wang, B. Li, L. Tian, "Multi-modal medical image fusion using the inter-scale and intra-scale dependencies between image shift-invariant shearlet coefficients", Information Fusion, 2012.

[10]. R.J.Sapkal, S.M.Kulkarni, "Image Fusion based on Wavelet Transform for Medical Application", IJERA, ISSN: 2248-

9622, Vol. 2, Issue 5, pp.624-627, September- October 2012.

[11]. C.T. Kavitha, C. Cellamuthu, R. Rajesh, “Medical Image Fusion Using Combined Discrete Wavelet and Ripplet Transforms”, Elsevier-International Conference on Modeling Optimisation and Computing, pp.813-820, 2012.

[12]. P. Phanindra, J.Chinna Babu, V.Usha Shree, “FPGA Implementation of Medical Image Fusion Based on DWT”, International Journal of Advanced Research in Computer Science and Software Engineering, ISSN: 2277 128X, Volume 3, Issue 9, September 2013.

[13]. Gaurav Bhatnagar, Q.M. JonathanWu, Zheng Liu, “Directive Contrast Based Multimodal Medical Image Fusion in NSCT Domain”, IEEE Transactions on Multimedia, Vol. 15, No. 5, August 2013.

[14]. Mirajkar Pradnya P, Ruikar Sachin D, **“**Wavelet based Image Fusion Techniques”, International Conference on Intelligent Systems and Signal Processing, 2013.

[15]. K Sharmila, S Rajkumar, V Vijayarajan, “Hybrid method for Multimodality Medical image fusion using Discrete Wavelet Transform and Entropy concepts with Quantitative Analysis”, IEEE Advancing Technology for Humanity, International conference on Communication and Signal Processing, April 3-5, 2013.

[16]. Sudeb Das, Malay Kumar Kundu, “A Neuro-Fuzzy Approach for Medical Image Fusion”, IEEE Transactions On Biomedical Engineering, 2013.

[17]. A.P. James, B.V. Dasarathy, “Medical image fusion: A survey of the state of the art”, Information Fusion, vol.19, pp. 4-19, 2014.

[18]. Laxman Tawade, Abida Bapu Aboobacker and Firdos Ghante, “Image Fusion Based on Wavelet Transforms”, International Journal of Bio-Science and Bio-Technology ,Vol.6, No.3, pp.149-162,2014.

[19]. K.P.Indira, Dr.R.Rani Hemamalini, “Analysis on Image Fusion Techniques for Medical Applications”, IJAREEIE, Vol. 3, Issue 9, September 2014.

[20]. Himanshi, Vikrant Bhateja, “An Improved Medical Image Fusion Approach Using PCA and Complex Wavelets”, IEEE-International Conference on Medical Imaging, m-Health and Emerging Communication Systems, pp.442-447, 2014.

[21]. Navneet kaur, Madhu Bahl, Harsimran Kaur, “Review On: Image Fusion Using Wavelet and Curvelet Transform”, IJCSIT, Vol. 5 (2), 2467-2470, 2014.

[22]. V.Savitha1, T. Kadhambari, R.Sheeba, “Multimodality Medical Image Fusion Using NSCT”, IJREAT, ISSN: 2320 - 8791, Volume 1, Issue 6, Dec-Jan, 2014.

[23]. M.Ramamoorthy, K.Anees Barvin, “Medical Image Fusion Using Gabor and Gradient Measurement”, International Journal of Innovative Research in Science, Engineering and Technology, ISSN (Online): 2319 – 8753, ISSN (Print): 2347 – 6710, Volume 3, Special Issue 3 March 2014.

[24]. Umer Javed, MuhammadMohsin Riaz, Abdul Ghafoor, Syed Sohaib Ali, Tanveer Ahmed Cheema, “MRI and PET Image Fusion Using Fuzzy Logic and Image Local Features”, Scientific World Journal, Article ID 708075, Volume 2014.

[25]. Deepika.L, Mary Sindhuja.N.M, “Performance Analysis of Image Fusion Algorithms using HAAR Wavelet”, International Journal of Computer Science and Mobile Computing, ISSN 2320–088X, Vol.3 Issue.1, pg. 487-494, January- 2014.

[26]. Nayera Nahvi, Onkar Chand Sharma, “Implementation of Discrete Wavelet Transform For Multimodal Medical Image Fusion”, International Journal of Emerging Technology and Advanced Engineering, ISSN 2250-2459, Volume 4, Issue 7, July 2014.

[27]. Abhinav Krishn, Vikrant Bhateja, Himanshi, Akanksha Sahu, "Medical Image Fusion Using Combination of PCA and Wavelet Analysis", IEEE- International Conference on Advances in Computing Communications and Informatics (ICACCI), pp.986-991, 2014.

[28]. Sun Wei, Hu Shaohai, Liu Shuaiqi, Sun Yuchao, "Infrared And Visible Image Fusion Based On Object Extraction And Adaptive Pulse Coupled Neural Network Via Non-Subsampled Shearlet Transform", IEEE- ICSP Proceedings, pp.946-951, 2014.