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A Survey on Image Fusion Techniques for Medical Applications.

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ABSTRACT

Image fusion is the process of combining information from two or more images of a scene into a single image in which the fused image contains more information than any of the input images. This technique retains more information and improves the quality of data. Image fusion is one of the important re-processing step in digital image reconstruction. This paper provides a review on some of the image fusion techniques like wavelet transform, contourlet transform, Daubechies complex wavelet transform, shearlet transform, discrete wavelet transform etc.
Keywords: Contourlet transform, wavelet transform, Daubechies complex wavelet transform, shearlet transform, discrete wavelet transform.

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INTRODUCTION

In the recent years, medical imaging has attracted increasing attention due to its critical role in health care. Medical image fusion has become more important with the development of the medical image technology in medical diagnosis. Various medical imaging techniques such as Computed Tomography (CT), Magnetic Resonance Imaging (MRI),Positron Emission Tomography (PET),Single Photon Emission Computed Tomography (SPECT)etc provides different information about the human body that are important in diagnosing the diseases. For example MRI provides better anatomical information while CT provides information about dense structures like bones and PET provides better information on blood flow with low spatial resolution.

A single mode of medical image cannot provide accurate and comprehensive information and hence the medical image fusion has become the focus of image processing. With rapid advancements in technology, it has become possible to obtain high quality fused image with both spectral and spatial information.

Image fusion is the process of combining multiple input images or some of their features into a single image without the introduction of distortion or loss of information [1].Image fusion aims to obtain information of greater quality[2]. Multimodality medical image fusion combines the complementary information of various modals into one image so as to provide far more comprehensive information and improve the reliability of clinical diagnosis and therapy.[3]Medical image fusion method is broadly classified into three categories - feature based, pixel based, and decision making based medical image fusion. Because of different imaging mechanism and high complexity of body structures and tissues different medical imaging system can provide non-overlay and complementary information.

Recently, a variety of image fusion techniques has been developed which is classified into two- multi-scale decomposition based image fusion methods and non multi scale based image fusion methods. Muti scale decomposition methods includes pyramid algorithms, wavelet, wedgelet, bandelet, curvelet and contourlet transform methods. Non muti scale decomposition method includes techniques like weighted average, non-linear and estimation theory based methods. Discrete Wavelet Transform (DWT) contourlet transform and Principal Component Analysis(PCA) has become popular image fusion techniques in recent years than existing image fusion techniques. These methods perform better than simple averaging, maximum, minimum. The quality of fused images are analyzed using various parameters like Peak Signal to Noise Ratio(PSNR), Correlation coefficient, Entropy, Root Mean Square Error(RMSE) etc.

This paper is organized as follows: Section II describes various image fusion techniques by different authors. and finally conclusion is presented in section III.

PRIOR WORK

Huimin Lu et al has proposed the maximum local energy method to calculate the low-frequency coefficients of images and the results obtained are compared with wavelets. [4]In this paper, the coefficients of two different types of images through beyond wavelet transform are obtained. The low-frequency and high frequency coefficients are selected by maximum local energy and sum modified Laplacian method. Finally, the fused image is obtained by performing an inverse beyond wavelet transform. Three types of images (multi focus, multimodal medical and remote sensing images) are used in this experiment and the results are analysed quantitatively . The experimental results reveal that maximum local energy is a new strategy for attaining image fusion with satisfactory performance. Through a large number of experiments, it is inferred that MLE-bandelet transform and MLE- contourlet transform are superior for processing multi focus images. MLE-contourlet transform is better in processing the CT/MRI remote sensing images than the MLE-bandelet transform.

Rajiv Singh et al has proposed fusion of multimodal medical images using Daubechies complex wavelet transform.[5] Multimodal medical image fusion suffers from drawbacks like shift sensitivity, lack of phase information and poor directionality. To overcome the above drawbacks , the author has used complex wavelet transform which is approximately shift invariant and provides phase information. The DCxWT is capable of preserving information about the edges and also provides phase information which is highly immune to noise and contrast distortions. The proposed image fusion technique is visually and quantitatively compared with wavelet domain (Dual tree complex wavelet transform (DTCWT), Lifting Wavelet Transform (LWT), Multi Wavelet Transform (MWT), Stationary Wavelet Transform (SWT) and spatial domain (Principal Component Analysis (PCA), linear and sharp), Contourlet Transform (CT) and Non-Subsampled Contourlet Transform (NSCT) based image fusion methods. For comparison the author has used five fusion metrics, namely entropy, edge strength, standard deviation, fusion factor and fusion symmetry. Comparison results has proved that performance of the proposed fusion method is better than any of the above existing fusion methods. The proposed method is further tested against Gaussian, salt & pepper and speckle noise to examine the robustness of the proposed method.

Lei Wang et al has proposed Multi-modal medical image fusion method in the shift-invariant shearlet transform domain. [6]SIST technique has been carried out using non-subsampled pyramid filter scheme and shift invariant shearing filters. The probability density function and standard deviation of the SIST coefficients are employed to calculate the fused coefficients. A major advantage of the shearlet technique than NSCT is that there are no restrictions on the number of directions for the shearing, as well as the size of the supports. In addition, inverse discrete shearlet transform requires only a summation of the shearing filters . This results in an implementation that is computationally more efficient. The author has also considered the dependencies of the SIST coefficients and inter subbands in the proposed fusion rule, therefore more information from the source images is transferred into the fused image.

Gaurav Bhatnagar et al has proposed a new fusion framework based on non-sampled contourlet transform.[7] The author has employed pixel level fusion in this paper. In this technique the source images are first decomposed using NSCT technique. The high and low frequency components are fused using phase congruency and directive contrast technique. Finally inverse NSCT is applied to obtain the fused image. The phase congruency technique provides a contrast and brightness invariant representation of low frequency coefficient. Directive coefficient is used to determine frequency coefficients from high frequency region. Using this technique the author selects the most prominent texture and edge information from high frequency coefficients. This technique has proved to be more efficient than existing wavelet techniques.

Sabalan Daneshvar et al has proposed a new image fusion technique by combining the Intensity-Hue-Saturation (IHS) and Retina-Inspired Models (RIM). Though the IHS technique has been most commonly used in the practical applications, this technique leads to spectral distortion in the fused image. Though the fused results of Retina-Inspired Model have low spatial resolutions their spectral intensities remain strong. [8]To prevent spectral distortion an IHS and RIM integrated fusion approach has been proposed in this study. This algorithm coordinates the advantages of both IHS and RIM fusion methods to improve the functional and spatial information content. Visual and statistical analyses proves that the proposed algorithm has significantly improved the quality of fused images . In the proposed method, the color information was least distorted and the spatial information were as clear as the original MRI.

Mutual Information (MI) quantifies the information that is shared between two random variables and has been widely used as a similarity metric for multi-modal and uni-modal image registration. [9]A drawback of MI is that it considers only the intensity values of corresponding pixels. Hassan Rivaz et al has proposed Contextual Conditioned Mutual Information (CoCoMI) technique, which conditions MI estimation on similar structures. In this work, the author has utilized contextual information to condition MI. The contextual analysis consists of calculating patch similarities in a neighborhood and recording the location of most similar patches. The author has used two complementary histogram descriptors for contextual analysis. The author used the contextual information to constrain the shape of the joint histogram. Further the author has presented the results on non-rigid registration of UltraSound (US) and Magnetic Resonance (MR) patient data from image-guided neurosurgery trials performed in the institute and publicly available in the BITE dataset. Using simulation and patient data, it has been showed that CoCoMI performs better than state of the art non-rigid registration methods.

In order to overcome the computational complexity and manual parameterization in Multi-resolution analysis, [10] Zhiping Xu et al has proposed a novel pixel-level fusion algorithm for multi-modal medical images based on their local extrema. This method enables the decomposition of input images into coarse and detailed layers . The coarse layer is the average of the two interpolates, evaluated at each pixel, and provides an estimate of the local mean about which the vibration occurs. The detailed layer can be obtained by subtracting the coarse layer from the original input image. The coarse layer contains the intensity distribution and an easily perceivable amplitude of intensity variation of the original image. The detailed layer contains the texture pattern and local edge information of the original. In the medical image, the coarse layer reflects anatomical and functional information of tissues and organs, whereas the detailed layer reflects the texture and local edges of the tissue. This algorithm does not include an image registration feature, so that the author assumed that the multi-modal images to be fused are already perfectly registered by some kind of registration method so that corresponding features coincide pixel-to-pixel. Further, in the proposed method input images were assumed noise-free. Noise in the input image will affect the detailed layer, and so in future research, the author has assumed that he shall work to detect and reduce the effects of noise on the detailed layer and develop a more robust medical image fusion scheme.

The reason for this study is to ascertain the precision of a novel three-dimensional (3D) imaging joining method of the oesophagus. [11]Fernando A. Scazzuso et al incorporated 94 back to back patients with symptomatic atrial fibrillation (AF) atrial fibrillation (AF) who underwent ablation. All patients had a CT performed former methodology that is incorporated to the 3D recreation electromechanical guide of the chamber and the oesophagus. Amid the methodology, a quadripolar electrophysiology catheter put in the throat was utilized for mapping and to screen oesophagus position. Coordinated (combination) pictures are utilized to determinate the oesophagus position contrasted with the left chamber back divider and its relationship with P V ostiums. There was a significant oesophageal security amid the method (88%), with just a little measure of movement. Despite the fact that this strategy has given better results, it has a few impediments also. Despite the fact that the example size of the study may be little, the author has considered it sufficiently large to represent the current number of ablations. Additionally, the present study is observational, single focus involvement with no arm correlations. Further, it obliges catheter insertion into the throat, which can possibly build the danger of mucosal harm. Clinically significant oesophageal confusions has not been seen in the present study. At long last, point by point-to-point approval of combination pictures were not performed.

Jianwen Hu et al has proposed a novel multiscale geometrical examination called the Multiscale Directional Bilateral Filter (MDBF) which presents the non subsampled directional channel bank into the multiscale two-sided channel. [12]The multiscale directional respective channel is developed through consolidating the MBF with the NSDFB. The MBF is, right away, connected to the first image to get the itemized subbands and the rough guess subband. Gaussian filtering is a standout amongst the most ordinarily utilized routines for picture smoothing. The fundamental presumption of Gaussian sifting is that images shift gradually over space. However, this suspicion fails at the edges. To overcome this issue, the bilateral filter has been developed. Bilateral filter is a nonlinear, non iterative and local technique that can smooth images while protecting the edges. Through combining the characteristic of preserving edge of the bilateral filter with its ability to capture directional information of the directional filter bank, the MDBF can represent the better intrinsic geometrical structure of images..To validate the effectiveness of the MDBF, the MDBF is applied to multisensor images. The experimental results reveals that the proposed method provides superior fused images in term of quantitative evaluation metrics. However, the MDBF is more time-consuming than traditional methods because this method has many directions and is space variant and non subsampled.

Teleradiology allows transmission of medical images for clinical data interpretation to provide improved e-health care access, delivery, and standards. [13] P. Viswanathan et al has proposed a joint FED watermarking system for addressing the issues like image retention, fraud, privacy, malpractice etc. that occurs during image transmission. This technique combines a region based substitution dual watermarking algorithm using spatial fusion, stream cipher algorithm using symmetric key and fingerprint verification algorithm using invariants. The dual watermarking system, introduces two different embedding schemes, one used for patient data and other for fingerprint features, reduces the difficulty in maintenance of multiple documents like authentication data, personnel and diagnosis data, and medical images. The spatial fusion technique provides better quality than other fusion techniques. The four step stream cipher algorithm using symmetric key for encrypting the patient data with fingerprint verification system using algebraic invariants improves the robustness of the medical information. Experimental results have proved that the ROI and fingerprint embedded in the medical image using dual embedding scheme in different location with and without spatial fusion verifies all the security issues for teleradiology with maintainance of quality of the medical image by algorithm with less time and computation complexity.

Single-photon discharge registered tomography (SPECT) pictures alone are hard to see in determination, since anatomical structures are truant from the information. Studies have been performed to consolidate the SPECT picture by the Magnetic Resonance (MR) picture. [14] Due to the low likeness between unique pictures, intertwined results are constantly obscured bringing about the loss of some critical anatomical structures. [14] Tianjie Li et al has solved these problems by the variable-weight matrix which is estimated by minimizing the cost function using the simplex method. This technique avoids the deficiency of the traditional transparency technique in the fusion of MR and SPECT images. It has been further coordinated with the multi scaled fusion rule so that fused images are bright in luminance and definite in details. The highlight of the proposed system is its intuitive properties which permits slow variation between original images and the easy control of detail performance. Additionally , this method holds the reading behavior of original images, which makes the clinical evidence easy to recognize and understand. The fusion rule is then presented with the GIHS framework and the Non Subsampled Contourlet Transform (NSCT) for the bright visual perception, better detail preservation and detail performance control. Analyses on the typical cerebrum map book shows the predominance of the proposed system than existing image fusion techniques.

Rui Shen et al has put forward a novel cross scale fusion for volumetric-images. This technique takes into account both intrascale and interscale consistencies.[15] The author has put forward an efficient colour image fusion scheme for the case of two monochrome source images. To achieve good contrasts in red green and yellow blue channels, the author has considered red, green, blue and yellow colour arranged on a colour circle where red-green axis is orthogonal to blue-yellow axis. If colour contrast has to be maximized in a colour fused image, their hues should come from 2 opposite quadrants, or from 2 orthogonal hues on a colour circle. With all the above considerations in mind, the author has developed the following techniques. Finally the author has evaluated his volumetric image fusion scheme using both synthetic and real data. The above technique is not only useful in applications like diagnosis, but offers flexibility of combining different modalities of our own choice. The author has finally concluded that the proposed fusion rule offers better results than existing method and is about to carry his future work on 4D medical images.

CONCLUSION

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

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