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A Survey on Multi – Modality Medical Image Fusion

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***Abstract*— Medical imaging modalities such as magnetic resonance imaging (MRI), computed tomography (CT), positron emission tomography (PET) etc have been developed and widely used for clinical diagnosis. In brain medical imaging, MRI image shows structural information of the brain without any functional data, where as PET image describes functional information of the brain but with low spatial resolution and so on. These multi-modality images contain important information for the accurate and effective diagnosis of brain diseases. Thus, fusing various modalities of images in medical field into a distinct image with more detailed anatomical information and high spectral information is highly desired in clinical diagnosis. This work presents a detailed literature review done on image fusion and also the concepts and materials that helps for clear understanding of various fusion techniques.**

Keywords— Multi – modal medical images; image fusion; clinical diagnosis.

I. Introduction

In medical field, both the qualities of spectral and spatial data in a solitary image is highly desired by the doctors (radiologists) for various purposes like researches, monitoring, accurate diseases diagnosing and also for treatment process [1]. Using single modality image, it is quiet difficult to obtain information of this type since, Computed Tomography (CT) images are most popular for showing bone structures and lacks in providing information about the tissues; at the same time, Magnetic Resonance Imaging (MRI) provides soft tissue information and lacks in boundary information, Positron Emission Tomography (PET) image reveals actual information of flow of blood but lacks boundary information and so on. Thus, every single modality image has its own drawbacks in providing needed information because each image is captured with different radiation power. In order to overcome this, it is highly required to obtain information from multiple modalities which is used for clinical diagnosis. In this situation, fusion is a technique used to combine multimodality medical images such as CT, MRI, and PET etc. Image fusion technique that integrates suitable information from various modalities of input images into a fused distinct image where the resultant image provides better inventive information in comparison with the input images which are used for fusion [2]. This fused information of image is used in many fields such as Medicine, Agriculture, Aeronautics, Law Enforcement etc.

II. Literature Review

Image fusion technique integrates suitable information from various modalities of input images into a fused distinct image of the same prospect that contains crucial information features of the unique image where a human can use it with more convenience. An image fusion method based on a particular region is developed, which reveals that this method is better than fusion based on pixels. Fusion based on pixel level images affects high contrast of image due to blurring effect. A region based method which has less noise and with high contrast [3], but with losing of some data is achieved using this technique.

Fusion algorithm for a 3D multimodal images based on multi-resolution wavelet [4] plays a significant role to divide an image into different frequency portions. Fused image is visualized using this method by the application of color to input images. When it is passed through rescaling and re-sampling filters, it should have both image slice number and spatial resolution almost equal. 3D images which are decomposed through the proper fusion rules are initiated and reconstructed using this method. Progressive multistate and multi-determination picture preparing procedures, pyramid disintegration are the establishment for the majority of picture combination calculations. Highlight extraction and measurement diminishment are a percentage of the critical elements of PCA, valuable for picture combination. A technique for consolidating pyramid and PCA methods [5] have been developed which is utilized to complete the quality investigation without reference picture.

In many medical applications, image fusion is the most significant tool for the interpretation of the quality of images and the data acquired through this is either functional or having high spatial resolution. Usually, MRI image shows structural information of the brain without any functional data, where as PET image describes functional information of the brain but with low spatial resolution. Therefore, image fusion is conceded to improve functional image's spatial resolution through which original functional characteristics is preserved [6] with no spatial distortion. Two fusion methods, IHS&LG+ and IHS&LG++ was proposed for fusion by choosing suitable decomposition scale and orientation for different regions of images based on IHS and log-Gabor wavelet [7] in the first method for fusing PET and MRI images whereas in the second method, the intensity of the fused image is refined to further reduce color distortion and to put into effect the anatomical structure. This method uses the hue angle of each pixel in PET image to divide both PET and MRI pictures into districts of low and high movement. The fused intensity of each region is obtained by applying inverse log-Gabor transform. Experimental results based on this technique reveals that the final fused image is on three sets of brain disease images illustrated that input images fused by IHS&LG+ are with less color distortion and with the same structural information as the images fused by IHS & RIM.

A procedure of forming a fused image which is mainly used for disease diagnosis [8] from different images is illustrated with good results including many performance metrics. Inputs taken are MR-T2 and CT scans to which fusion techniques like Mamdani sort least aggregate mean of maxima and Redundancy Discrete Wavelet Transform are connected and tested.

A technique for fusing PET- MRI image using wavelet and spatial frequency method is proposed which eliminate the influence of image imbalance [9]. This method reduced blur effect, improved the clarity which is useful for clinical diagnosis. The result analysis indicated that suggested system is comparatively better than the conventional algorithm based on PCA in terms of good visual & quantitative fusion results.

Based on DWT, two algorithms namely pixel averaging & maximum pixel replacement approach [10] with very good fusion results is proposed which eliminates the drawbacks of PCA technique. An approach regarding low and high activity regions of wavelet transform of brain is illustrated which can generate proficient fusion result by slightly changing the gray matter (GM) anatomical structural information and then patching white matter (WM) spectral information [11], followed by wavelet decomposition and gray-level fusion. A novel adjustment for the pixel intensity in the non-white matter area of high-activity region in the gray-level fused image will bring more anatomical structural information into the final color fused image. Spectral information patching in the white matter area of high-activity region will preserve more color information from PET image for the white-matter area. Many medical applications use multimodal medical image fusion for the repossession of corresponding data from medical images.

A new algorithm based on Daubechies transform coefficients [12] for fusion is proposed and is compared using region segmentation and spatial frequency method. This work also covered the comparison of performance evaluation metrics such as entropy, standard deviation and fusion factor between input images and output images. Medical multimodal image fusion is an important method of medical imaging to obtain information from different multimodalities of medical images. An innovative multimodal medical image fusion method by means of Daubechies complex wavelet transform using mixed fusion scheme [13] is proposed based on energy where image fusion is performed using spatial or transform domain methods. A scheme for image fusion which is helpful for determining average information of image is also described which gives better fusion results.

Images that are obtained by combining magnetic resonance imaging and computed tomography images helps the doctor in analyzing more information and helps in clinical testing [14]. In many fields we have been using technologies for integrating the PET and CT images that helps in perfect fusion. The fusion image has the advantage of locating the pathological changes using the characteristics of computed tomography and has the ability in detecting the pathological changes using characteristics of PET. Fused image detects and locates the changes in the nature of the disease, especially changes in body tissues and organs [15].

Physicians can obtain the relevant information using multimodality medical image fusion, which is helpful to diagnose the disease. Wavelet decomposition for decomposing image happens in such a way that, low frequency components are achieved by performing maximum absolute values and it is verified using consistency. Maximum local variance rule helps in selecting the high frequency coefficients. Inverse wavelet transform added with combined wavelet coefficient is used to reconstruct the fused image. Multimodality medical image statistics that is obtained from CT and MRI helps in improving the image content and in getting useful information, used for medical diagnosis and treatment. Information about soft tissues and denser tissues can also be obtained by this technique - Fast Discrete curvelet Transform [16] using Wrapper algorithm. To get more data regarding the image, the images are fused at different resolutions and intensities.

The content of the image can be improved by using various imaging tools that helps in mixing useful information by removing the excessive information from registered source images. Taking into consideration all limitations of image fusion based on transform level and pixel level method, comparative analysis is conducted and quantitative analysis is performed using entropy, UIQI, fusion factor, fusion symmetry and processing time. Combination of CT and MRI images is used for analysis purpose and the fused images obtained from fuzzy inference system helps in achieving the better result [17].

Using fast discrete curvelet transform that analyses the curved images [18], it is possible to fuse an MRI and CT image which helps in diagnosis of disease. Single Photon Emission Computed Tomography (SPECT) image does not contain anatomical information; hence it is difficult to use it for perception and diagnosis of disorders. MRI has high spatial resolution that shows brain tissue anatomy and SPECT has low spatial resolution and shows brain function. In order to remove the individual disadvantage, it is required to combine MRI and SPECT, through which it is possible to obtain both functional, anatomical information, spatial and spectral features. Alternative methods such as IHS and Multi-resolution fusion methods are used in preserving spatial and spectral information respectively. The proposed method [19] involved minimizing distortions of fused images compared to other methods. The advancement in digital image processing helps in extracting the features of images that leads to the development of image fusion.

Wavelet and watershed algorithm transforms are the two approaches [20] used for image fusion. The detailed coefficients of the image are obtained by decomposing the source image and the achieved sub image are segmented using watershed algorithm to get the fused image. The images that are segmented are fused using Wavelet Transform- Fuzzy C-Means (WT-FCM) algorithm. The fused image should not contain any undesired feature and the fusion process should possess relevant information. Higher accuracy and reliability are provided by fused image.

Daubechies complex wavelet transform is also used which has less computational requirements and phase information for fusing images. This new multilevel Daubechies complex wavelet transform (DCxWT) works well on the principle of multimodal medical image fusion method which follows multi-resolution. In this method complex wavelet coefficients [21] are fused using maximum selection. For clinical application, fusion of multimodal brain imaging is important as PET indicates the brain function and MRI shows the brain tissue anatomy.

A new technique is proposed in which YCbCr is performed on the multispectral image to get luminance, blue-difference and red-difference chromatic components and using DWT depending on PCNN (pulse coupled neural network) to combine luminance component(Y) and MRI image. Finally by applying the inverse YCbCr transform to the new luminance and to the old blue and red difference chromatic components, the fused image is obtained. PCNN [22] is used as it has pulse synchronization and global couple characteristics and is suitable for image processing and fusing images.

Based on merging of complementary diagnostic content using wavelets and Principal Component Analysis (PCA) [23] , a 2D- Discrete Wavelet Transform to preserve both spatial and spectral information is developed. To maximize the spatial resolution, PCA is applied to it. For better fusion results, Daubechies wavelet family has been selected, which improves the visual excellence of the fused image compared to other techniques.

Multimodality medical image data that has been derived from fusion of medical images of the same type such as MRI and CT helps in getting more and precise information which is more useful for clinical diagnosis. An Integer Wavelet Transform (IWT) [24] that is used to decompose anatomical and functional images and Neuro- Fuzzy, which is used to fuse wavelet coefficients is illustrated for a better fusion. Also, quantification of joint mutual information is analyzed using Fusion Factor (FF). Image fusion problem by analyzing image fusion with the help of contourlet transform and fuzzy and neural networks is also possible [25]. Fuzzy membership values helps in getting the linking strengths of neurons. Computational efficiency increases with usage of neural network having less complex structure and less number of parameters. The proposed scheme is with high contrast and lesser loss of detailed information of image. Massive prevalence of Alzheimer’s disease can also be diagnosed using non-invasive biomarkers, EEG MRI volumetric [26].

III. CONCLUSION

Review of the literature indicated that most of the researchers have worked on various fusion methods for medical images. Investigations from the detailed survey concluded that all these techniques mentioned above have either a serious side effect of color distortion, visual clarity or missing some anatomical structural information in the gray matter area of the high-activity region of the fused image. Also from these reviews, it is identified that many techniques adopted earlier for fusion has spectral distortion and lacks spatial resolution. In future, the main objective is to investigate a new solution to overcome identified artifacts by designing an image fusion method which is different from the regular simple Discrete Wavelet Transform (DWT) fusion method and to generate promising results by varying the anatomical structural information in the GM area and then patching the spectral information in the WM area to have better color preservation after the wavelet decomposition and gray-level fusion.

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