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Image Fusion Techniques for the Hybrid Multimodal Medical Images - A Literature Review

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ABSTRACT

Image fusion is defined as the process of registering and combining the information captured out of multiple images into a quality single image. The process of image fusion is widely utilized in the areas of remote sensing, medical field, satellite imaging and etc. Multimodal medical imaging gains significance since it is a prevailing tool for medical diagnosis. This paper aims at presenting the start of art of the importance of image fusion techniques involved in the field of medical imaging and the need for the multimodal medical imaging. Also it provides the various hybrid multimodal medical image fusion techniques that have been implemented so far.

KEYWORDS : Deep Learning, Medical Image, Data Analytics, Image Fusion, Modality

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1. INTRODUCTION

Multimodal Image fusion in the field of medical is said to be a technique of extracting information which is complimentary from the multiple images obtained from the multiple modalities. The fusion process aims at improving the quality of the image so that the fused image will be helpful for the medical diagnosis. Some of the modalities used in the medical field are Positron Emission Tomography-PET, Magnetic Resonance Imaging-MRI and Computed Tomography-CT. All these modalities provide information about the body tissues of the human but the amount of information varies based upon the type of modality being used. For an illustration CT images can display the bone structure but it cannot identify the physiological changes. MRI images can display the details of the soft tissues by using magnetic field and radio waves. Thus combining these two images can reduce the redundancy and aids in better diagnosis.

2. MATERIALS AND METHODS

The image fusion methods for the medical images can be classified into two domains[1,2] They are spatial domain and frequency/transform domain[3]. The classification of image fusion technique is depicted in Figure 1.

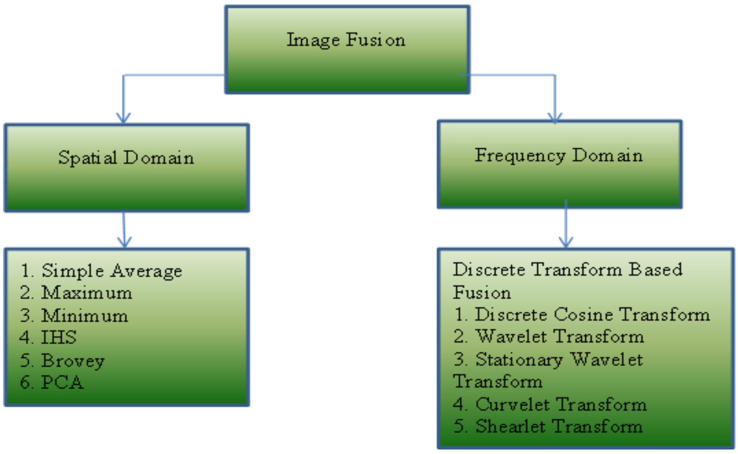

Figure 1 Classification of Image Fusion Techniques

2.1 Spatial Domain Image Fusion

The spatial domain techniques are also known as simple image fusion techniques. Some of the simple image fusion techniques are min-max, simple average, selection of maximum or minimum pixel value, simple block replace techniques[4] which are used to fuse images. In the simple average technique of image fusion, the resultant merged image is obtained by taking the average of the pixels from the input images. Selection of maximum or minimum technique chooses the maximum or minimum pixel values from the input images to get the fused image. In the max-min method, the fused image is obtained by taking average of the smallest and largest pixel value of the input images. In Simple block replace technique, each pixel in the image is added with its neighboring pixels and block average is calculated. Apart of these basic techniques, other spatial domain methods are weighted averaging method in which various weights are assigned to the input images. Pixel of the fused image is gained by calculating weighted sum of the pixels of the input images. In Principal Component Analysis (PCA)[5], set of correlated variables are converted into a set of uncorrelated variables that are known as principal components. IHS – Intensity, Hue and Saturation transform provides the visual representation of an image in a controlled manner. Similar to IHS transform Brovey method is used to produce high contrast RGB image based on the three properties. It is also known color normalization transform which is used to preserve the phantom feature of each pixel and the information are transformed to obtain the high resolution images[6].

2.2 Transform Domain Image Fusion

In the transform/frequency domain method of image fusion, the input images are first decomposed into various scales and then transformed into coefficients which then are combined together based on the fusion rules[7]. The fusion rules are then applied to the images to obtain the final fused image by imposing inverse transform onto the fused coefficients. This technique involves various discrete transform methods like Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Curvelet Transform (CT), Shearlet Transform (ST) and etc.

2.2.1 Discrete Wavelet Transform (DWT): In DWT, the informative and approximate coefficients are obtained by decomposing the input images. A fusion rule is then applied to merge the coefficients from which the resultant fused image is acquired by the inverse wavelet transform (IWT)

2.2.2 Discrete Cosine Transform (DCT): DCT is used to convert the images from spatial domain into frequency domain by dividing the images into various sub bands.

2.2.3 Curvelet Transform: The curvelet transform is used to handle discontinuities from the edges of the images. It is a ridgelet based transform technique in which the input images from various modalities are segmented into a number of coinciding tiles to capture the curve details[8, 9]. From the coinciding tiles edge detection is performed to observe the details of images more precisely. It works in 4 stages:

- Decomposing sub-band
- Smooth-Partitioning
- Re-normalization and
- Analysis of Ridgelet

The decomposed wavelet sub-bands of the input images are obtained during the first stage and through the partial image reconstruction, curvelet sub-bands are obtained at several stages. In the second stage, decomposed image at each sub-band is processed by applying smooth-partitioning as windows into squares of suitable scale. In the re-normalization stage, further the square is restructured as unit scale. At last the curved edge details of the input images are acquired by the application of ridgelet transform.

2.2.4 Shearlet Transform: The anisotropic features in a multivariate problem are efficiently encoded by the shearlet transform. Shearlet Transform is considered to be the extension of wavelet transform which is used to incorporate the multi-variate functionalities. In Shearlet Transform, the decomposition of the input images is performed initially, then the fusion rules are implemented onto the decomposed images and finally an inverse shearlet transform is applied for the reconstruction of the image to obtain the fused image with better visual quality[10].

2.3 Need for Hybrid Multi-modal Medical Image Fusion

Achieving high-quality image is a cumbersome task while using the basic image fusion methods for combining two different modal images. Hence there arises a necessity for hybrid model for the fusion of multimodal medical images. The hybrid fusion of images is performed by coalescing the spatial domain with transform domain technique which proliferates the performance and quality of the fused image[11]. Yet there is another way of hybrid fusion, in which two stage transformations are applied to the input images before carrying out the fusion process. Thus in a nutshell with the implementation of hybrid model for the fusion of images, visual quality of the images shall be increased by subsiding the image artifacts and noise[12].

3. DISCUSSION

Image Fusion is a method to obtain images from different sources and combining them into a single image to retrieve information which will be useful for various purposes. Image fusion extends its functionality in the fields of medical imaging, remote sensing, manufacturing process, computer vision and etc. Several techniques are available to perform image fusion in spatial and transform domain. Each and every technique has its own advantages and disadvantages. In order to obtain high quality fused image, hybrid multimodal image fusion is adopted which combines both the features of spatial and transform domain.

4. CONCLUSION

The simple fusion techniques under the spatial domain like simple block replacing techniques, selecting minimum, selecting maximum, selecting max-min and simple averaging techniques are not suitable for real time applications as they produce noisy, hazy and low contrast images. Other techniques like Principal component analysis (PCA), IHS and Brovey yields color distorted images even though those techniques are computationally efficient, fast and simple. Images with high spatial quality are obtained by fusing using PCA but the images are degraded spectrally. High sharpening of the image is achieved with the help of IHS technique. Discrete Cosine Transform (DCT) technique can be applied to the images with the block size equal and above 8x8 and it is also suitable for real time applications. Better Signal to Noise Ratio (SNR) is obtained by using the Discrete Wavelet Transform which also achieves the minimization of spectral distortion. On the other hand, the wavelet transform cannot handle the edges and curves of the images under consideration due its isotropic nature. Though the Curvelet Transform is able to handle the edges and curves of the images during the process of fusion, performance of the transform based fusion process is degraded due to local dissimilarity in the images. Each and every algorithm for the image fusion process has its own pros and cons. Thus, it can be concluded that no fusion algorithm outpaces the others. Based upon the type of application, both the qualitative and quantitative assessment methods should be applied to decide upon the best fusion algorithm.

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