

Chapter 28

Medical Image Fusion in Wavelet and Ridgelet Domains: A Comparative Evaluation

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ABSTRACT

Medical image fusion facilitates the retrieval of complementary information from medical images and has been employed diversely for computer-aided diagnosis of life threatening diseases. Fusion has been performed using various approaches such as Pyramidal, Multi-resolution, multi-scale etc. Each and every approach of fusion depicts only a particular feature (i.e. the information content or the structural properties of an image). Therefore, this paper presents a comparative analysis and evaluation of multi-modal medical image fusion methodologies employing wavelet as a multi-resolution approach and ridgelet as a multi-scale approach. The current work tends to highlight upon the utility of these approaches according to the requirement of features in the fused image. Principal Component Analysis (PCA) based fusion algorithm has been employed in both ridgelet and wavelet domains for purpose of minimisation of redundancies. Simulations have been performed for different sets of MR and CT-scan images taken from 'The Whole Brain Atlas'. The performance evaluation has been carried out using different parameters of image quality evaluation like: Entropy (E), Fusion Factor (FF), Structural Similarity Index (SSIM) and Edge Strength (Q_{AB}^F). The outcome of this analysis highlights the trade-off between the retrieval of information content and the morphological details in finally fused image in wavelet and ridgelet domains.

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1. INTRODUCTION

1.1. Overview of Medical Image Fusion

'Medical Image Fusion' is the process of combining and merging complementary information into a single image from two or more source images to maximize the information content of images and minimize the distortion and artifacts in the resulting image (Dasarathy 2012). The complementary nature of medical imaging sensors of different modalities, (X-ray, Magnetic Resonance Imaging (MRI), Computed Tomography (CT)) have brought a great need of image fusion for the retrieval of relevant diagnostic information from medical images. The significance of fusion process is important for multimodal imaging modalities as images obtained from single modality provides only specific information; thus it is not feasible to get all the requisite information from image generated by single modality (Schoder et al. 2004; Nakamoto et al. 2009). To elaborate further, CT helps in accessing the extent of disease; yet it is limited in soft-tissue contrast, needed for differentiating tumors from scar tissues. On the other hand, MRI scores over CT in terms of soft tissue discrimination. This is necessary because the soft tissue contrast allows better visualization of tumors. This highlights the need towards the development of multimodality medical imaging sensors for extracting clinical information to explore the possibility of data reduction along with better visual representation. It is noteworthy here that the visualization of the region of interest can be further improved by application of non-linear contrast and edge enhancement techniques (Pandey et al., 2012, 2013; Bhateja et al., 2014).

1.2. Survey of Image Fusion Methods

In the past decades, several fusion algorithms varying from the traditional fusion algorithms like simple averaging and weighted averaging, maximum and minimum selection rule (Singh and Khare 2014) have been proposed. With the advancement of research in this field, algorithms such as Intensity–Hue–Saturation (IHS) (Choi 2006) and Brovey transform (BT) (Liu 2000) have been used to fuse medical images. In the recent years multi-resolution and Multi-scale approaches using Mallat (Mallat 1989), the à trous (Shena 1992) transforms, contourlet (Cunha et al. 2006; Ashmare et al. 2011) and laplacian pyramids (Sahu et al. 2014) have been proposed for image fusion. Fusion approaches employing wavelets analysis include transforms such as SWT, LWT, MWT (Watanadelok et al. 2009; Srivastava et al., 2011; Bhateja et al., 2013), RDWT (Singh et al. 2009), and complex wavelet (Himanshi et al. 2014). Yan Luo et al. (2008) used a combination of PCA with à trous wavelet transform which focused on the spatial and spectral resolutions. But, the technique did not laid emphasis on edge or shape detection, which are fundamental structures in natural images and particularly relevant from a visual point of view. Petrovic et al. (2004) proposed a 'fuse then decompose' technique which represented input image in the form of gradient maps at each resolution level. Although, it has been observed that the said approach by authors did not yield satisfactory performance but in turn increased the computational complexity due to the involvement of gradient maps. Sadhasivam et al. in their work (2011) applied PCA along with the selection of maximum pixel intensity to perform fusion. The said combination produced an image which had less structural similarity with the source images along with low contrast and luminescence. On the other hand, work of Xu et al. (2014) emphasized only on the contrast fusion rules neglecting other important features such as removing redundancy and representing lines in an image. Yang et al. (2010)

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