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Original Research Article

Nonsubsampled shearlet domain fusion techniques for CT–MR neurological images using improved biological inspired neural model

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ABSTRACT

The fusion of multimodality medical images performs a very crucial role in the clinical diagnosis, analysis and the treatment of especially in critical diseases. It is considered as an assisted approach for the radiologist by providing the composite images having significant diagnostic information acquired from the source images. The main purpose of this work is to develop an efficient framework for fusing the multimodal medical images. Three different fusion techniques are proposed in this paper that presents the CT and MR medical image fusion in nonsubsampled shearlet transform (NSST) domain using the adaptive spiking neural model. The NSST having different features and a competent depiction of the image coefficients provides several directional decomposition coefficients. Maximum selection approach and regional energy are utilized for low frequency coefficients fusion. Spatial frequency, novel modified spatial frequency and novel sum modified Laplacian motivated spiking model are used for every high frequency subimage component. Finally, fused images are reconstructed by applying inverse NSST. The performance of proposed fusion techniques is validated by extensive simulations performed on different CT-MR image datasets using proposed and other thirty seven existing fusion approaches in terms of both the subjective and objective manner. The results revealed that the proposed techniques provide better visualization of resultant images and higher quantitative measures compared to several existing fusion approaches.

1. Introduction

Currently, screening programs are mainly concentrated on the analysis of digital images and detection based these programs is a major asset in the struggle against the critical diseases like cancer, hemorrhage and Alzheimer and so many others. This is only the main reason for this attraction to prefer the multimodal images because there are several modalities of medical imaging, giving a different insight of the human body. However, because of the availability of different sources preferred by the doctors, the problem of information

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overloading occurs because of no one of the medical imaging modality is capable to produce reliable and accurate diagnostic information, particularly in critical diseases that is very rigorous, time consuming, costly, the chance of human errors and most importantly requires lots of years of experience. Hence, now there is a need to develop some efficient fusion approaches to fuse all the features of multiple source images into a single image that has a valuable clinical interpretation and suitable for diagnosis purpose.

In past years, lots of researchers have been concentrated on multimodal medical image fusion (MIF). Image fusion (IF) approach can be categorized at different pixel, feature or decision level. The fusion, at the pixel level is again categorized as spatial domain and transform domain [1]. In the spatial domain category, the first experimental demonstration of image fusion was reported in the 1980s that is based on average and weighted averaging the source images. This method leads to decrease the contrast of fused images and there would be a loss of the few structures in the fused image. Since then, the studies on image fusion have been investigated a range of spatial domain techniques. However, they suffer from spectral degradation. Partitioning of the image based fusion method was presented [2] that use the selection of the block based on its saliency or activity. In this method, selection of the block, their size and saliency criteria decide the quality of fused images. It also results in complete loss of information at each location that would distract the diagnosis based on the analysis of the radiologist. Some authors have employed neural network for pixel selection [3], or region selection [4]. The dimensionality reduction techniques based on the PCA were studied in [5,6]. To boost the performance of the IF/MIF approaches, the authors have also been approached toward the transform domain techniques.

Pajares et al. also presented a fusion approach with the similar or different resolution level of multiple images [7]. The MIF methods based on the wavelet transform (WT), although have been proven to be capable of capture of 1-dimensional singularity. It means it has only limited directional information, thus it causes artifacts along the edges that also contains very important diagnostic information. Besides this, authors [8] also proposed a nonsubsampled rotated complex WT based fusion approach by combining the CT and MR Image data and shown the extracted complementary and edge related features. Another study presented a dual tree complex WT based fusion approach by utilizing its features using principle component analysis [6]. To overcome the restriction of the WT, ridgelet transform is introduced to extract the edges [9], but it did not do well by capturing the curve edge details. So, Donoho et al. have introduced curvelet transform (CVT) to capture the 2-D singularities of any arbitrary curve [10]. Furthermore, the performance the IF methods has been analyzed with other multi-scale transformation techniques like curvelet transform [11,12], contourlet transform [13–15]. However, the results again suffer from the lack of shift invariance [16] with a limited number of directional decomposition. Bhateja et al. [14] introduced a cascade IF approach by decomposing the source images by the WT at stage 1 and the CNT at stage 2. Fusion rule has also been applied at a stage-1 based on component analysis and maximum fusion rule at stage-2 decomposition. Yang et al. have presented another fusion technique based on the nonsubsampled contourlet transform (NSCT) [17]. This method overcomes the limitation of CNT by removing the upsampling and downsampling after filtering. However, it has a problem of limited number of direction decomposition. Furthermore, another decomposition technique named as nonsubsampled shearlet transform (NSST) is introduced to overcome the limitation of the downsampling used in the forward and inverse transformation. The NSST also overcomes the problem of the contourlet transform (CNT) and the NSCT by providing a sufficient number of the directional coefficients of the reference images [18,19]. In past years, various MIF approaches based on all these decomposition methods have been stated [20]. Based on the outcomes of these methods, it is visualized that they yield better visual results. However, they have few drawbacks related to contrast reduction and loss of diagnostic information [3,21]. The PCNN and its modified versions with these aforementioned transform techniques have been presented in the IF/MIF domains by various authors in [19,22,23].

In this paper, three different fusion approaches are framed based on the concept of the NSST and biologically inspired feedback neural model (BIFNN), in which the feeding input is not provided as the conventional BIFNN for fusing the high frequency image coefficients. In addition to that, firstly spatial frequency, novel sum modified spatial frequency (NMSF) and novel sum modified Laplacian (NSML) are utilized as feeding inputs to the neural model for high frequency subimage coefficients in the NSST domain. The NSST decomposition can preserve more details present in the reference images and further enhance the visualization of the fused images. Furthermore, the performance of the fusion approach is analyzed visually and quantitatively by performing the extensive experiments on source CT and MR image pairs. In addition to this, the salient contribution of the proposed fusion framework in the NSST domain over several other fusion methods developed previously, is summarized as follows,

- This article presents a fusion approach for fusing the CT and MR neurological images that relies on the combination of the NSST and BIFNN by improving the feeding inputs. Moreover, shift-invariance, mutiscale and multidirectional properties of the NSST are used in the proposed fusion approach.
- Different fusion rules are proposed for combining the low and high frequency subimage coefficients.
- The biologically inspired feedback neural model is utilized for only high frequency NSST subimage coefficients based on the firing times and improved feeding inputs that can be able to capture the suitable differences and provide the resultant images with high contrast and clarity.
- For fusing the high frequency NSST coefficients, computation of the SF, NMSF, NSML is proposed and used as an input, individually to motivate the neural model that also able to capture the fine details present in the reference images.
- After the NSST decomposition, the computation of the regional energy is used for fusing the low frequency NSST approximation coefficients that provide the richer representation of informative content.

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