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Article *in* National Academy Science Letters · June 2016

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Natl. Acad. Sci. Lett.
DOI 10.1007/s40009-016-0498-1

SHORT COMMUNICATION

A New Contourlet Based Multiresolution Approximation for MRI Image Noise Removal

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Received: 9 May 2015 / Revised: 17 November 2015 / Accepted: 30 May 2016
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Abstract Modern medical diagnosis equipments included with digital signal processing capabilities have been used for fast and accurate diagnosis of brain structure abnormalities. In this paper a multi resolution based noise removal in magnetic resonance images for abnormality detection and recognition within the brain has been proposed. Wavelet and curvelet based multi resolution approximation has been used to decompose the inter-object relationships into different levels of detail. Contourlet based multi resolution approximation is presented in this work for better abnormality detection. Comparison of extracted feature points between the reference image and the image under study has been made in detection of the abnormality.

Keywords Multiresolution analysis · Contourlet transform · Wavelet transform · Magnetic resonance (MR) image

Magnetic Resonance Imaging (MRI) has been popular for visualizing and analyzing brain structures [1]. Based on this imaging technique, the main cerebral tissues namely white matter and grey matter are identified for studying brain structures. These two issues are key parts in the context for MRI based diagnosis and patient follow-up [2]. The normal MRI brain image and the image with abnormal tissue are shown in Fig. 1.

Multi resolution analysis follows the segmentation process, where the segmented patterns are further subjected to a multi resolution decomposition to extract the finest details in specific pattern [3]. Multi resolution analysis initiates with wavelet functions such as Haar, Daubechies to extract the desired features in the signal or image, because wavelets are efficient in approximating sharp discontinuities in most of the biomedical applications [4]. The MRI images have variety of curves and contours, advanced transforms like curvelet, ridgelet and cotourlet may be useful in providing better modeling and analysis. Contourlet transforms [5] are powerful for approximating images with smooth edges and they offer superior directional characteristics; which motivated to use them in present work. The curvelet transform [6], ridgelet transforms are capable of better approximating the finger print, face and palm print samples. The contourlet transform achieves better results than discrete wavelet transform (DWT), ridgelet and curvelet in image processing tasks such as noise removal, pattern matching and texture extraction due to its geometric representation [7].

In this paper, the multiresolution analysis using contourlet transform is proposed to detect the abnormality by means of removing film artifacts and noise components. Though wavelets are capable of identifying sharp edges, contourlet has the ability to capture the smooth edges of an image. The accuracy increase depends on the decomposition levels. To recover the original image, an inverse contourlet transform is used with the number of synthesis stages equal to the number of decomposition levels used. The proposed method for abnormality detection comprises of two main processes, they are noise removal and multi resolution analysis. Once the region has been extracted, it

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Published online: 11 June 2016

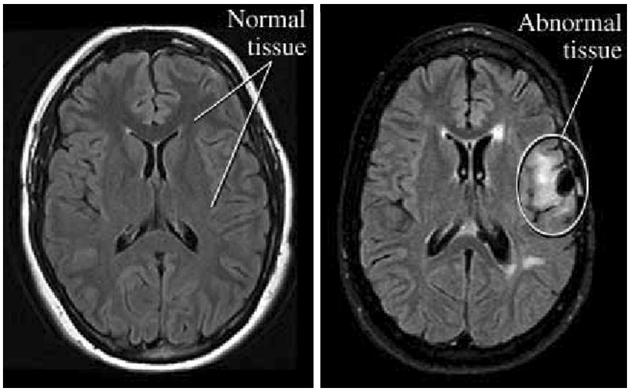

Fig. 1 Normal and abnormal MRI image

is subjected to a multi resolution analysis where the key feature points such as area, pixel density, mean and standard deviation are computed. These features are compared with the reference image for abnormality detection. Extra care should be taken while deciding the abnormal tissue, because the preprocessing stage may introduce unnecessary patterns or artifacts. The next step is to authenticate the results and find its accuracy. The process flow of the brain abnormality detection is shown in Fig. 2.

The input MRI image may be infected with certain multiplicative noise, blurring effects due to camera angles and deficient lighting conditions. After completing the image acquisition, the images are stored in database with patient's information and abnormality details, referred to as film artifacts. These film artifacts have to be removed by preprocessing techniques before the segmentation phase. Once the image has been preprocessed, it is followed by the segmentation stage for abnormality detection. Image segmentation is the process of partitioning an image into feature sets for improved analysis and the outcome would be generally boundaries, edges, contours etc.

Adaptive Median filter with a sliding window size of 7×7 is utilized to acquire smoothened edges and to preserve the edge properties. The extracted features can be applied to multiresolution analysis to extract critical features for identification of abnormal brain tissues. The statistical parameters such as mean, variance and standard deviation were used to assess the image. The image assessment parameters: pixel density and eccentricity were also utilized to detect the abnormality. To compare the performance of proposed contourlet technique with the existing wavelet based approaches, performance measures peak signal to noise ratio (PSNR), correlation coefficient (CC) and structural similarity index (SSIM) were considered.

The proposed work was carried on 40 abnormal images and 20 normal images obtained from MRI scan. Figure 3 illustrates the processing stages like edge detection, boundary drawing and finally extraction of the infected region for further analysis. The region of interest (ROI) is now subjected to multi resolution decomposition. Contourlet transform with 'pkva (Phoong, Kim, Vaidyanathan & Ansari)' filters can be used for image processing applications [8–10]. A five level decomposition with 'pkva12' filter has been utilized in this work for extracting more features. It yields 32 levels of directional sub bands and the energy of each sub band was computed which was also taken as a feature.

The energy levels may differ for the 40 abnormal and 20 normal samples taken. These energy levels offer a simple method to detect the abnormality by computing the difference. Once the energy of sub bands are computed, the statistical measures are computed. All the 40 abnormal and 20 normal images have been tested out of which one abnormal MRI sample was chosen for comparing with the reference sample. The superiority of contourlet transform over the wavelet transform techniques has been justified by comparing the proposed detection technique with the existing wavelet techniques and tabulated in Table 1.

The wavelet based noise removal in MR images is done based on decomposition and reconstruction [6]. Rbior wavelet based noise removal was considered for comparison purpose. In the curvelet transform based denoising, ridgelet has been used as a decomposing component and curvelet subbands were implemented using Rbior wavelet filters [11]. The curvelet based reconstructions produces visually sharper images than wavelet based reconstruction; hence the PSNR is improved to 47.14 dB. The denoising performance can be improved by directional filter based contourlet transform in which first Chebyshev uniform approximation has been applied [12].

The proposed technique is simple with slight increase in computational complexity due to directional multi resolution transform. However, the computational complexity is compensated by the efficient extraction of abnormality tissues. The proposed technique achieves the maximum PSNR of 48.14 which is higher than the wavelet based methods. The CC and SSIM are also high which makes the technique desired for brain abnormality detection and at the same time preserves good image quality.

Fig. 2 Process flow of brain abnormality detection

Input MRI Image → Noise Removal → Multiresolution Analysis → Processed MRI Image

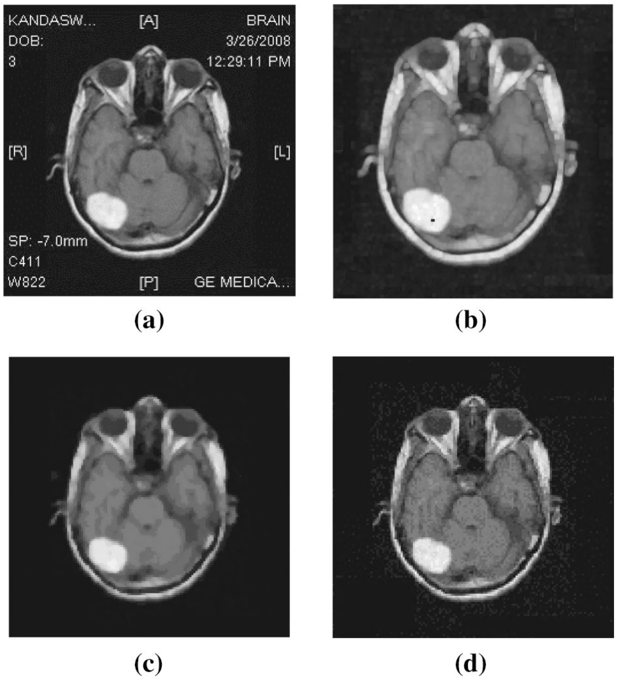

Fig. 3 **a** Recorded MRI image, **b** artifact removed image, **c** median filtered image, **d** filtered image using proposed technique

Table 1 Comparative performance of contourlet technique

Technique	Function	PSNR (dB)	CC	SSIM
Wavelet [6]	Rbior	46.52	0.924	0.918
Curvelet [11]	Rbior	47.14	0.946	0.923
Contourlet [12]	Pkva5	47.23	0.952	0.931
Proposed contourlet with multiresolution	Pkva12	48.14	0.974	0.962

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