An Integrated Approach for Medical Image Enhancement using Wavelet Transforms and Image Filtering

Muneer Ahmad [1], Noor Zaman [2], Low Tang Jung [3], Mudassir Ilyas [4], Dayang Awang Rohaya [5]

[1, 2, 4] College of Computer Science, King Faisal University, Saudi Arabia
[3, 5] Department of Computer Science, University Technology PETRONAS, Malaysia
mmalik@kfu.edu.sa

Abstract: Medical image enhancement is a fundamental optimization problem in computer science. Enhanced images can provide better insight of patient's disease and remedy for cure. Researchers have been paying great consideration over this challenging problem yet a significant optimal solution is need of time. This paper presents an integrated approach for medical image enhancement using wavelet transforms and image filtering. We have transformed the RGB image to a gray scale image, the transformed image was then filtered by low pass and high pass band discrete filters of third order. A soft threshold factor applied over decomposed wavelet coefficients obtained in high frequency spectral regions of signal produced a significant noise suppressed signal. Another application of prewitt operator in signal convolution helped in uniform smoothing in one direction and edge detection in other direction. The target smoothed noise suppressed image outperformed for a significant percentage of improvement by bringing significant results over traditional image enhancement techniques. We are ambitious to contrive new wavelet functions based on dyadic de-noising filters and threshold factors (soft and hard thresholds) to suppress the signal noise for robust medical image enhancement as an imminent anticipation.
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1. Introduction

Medical images are considered as a good source of information for the medical practitioners to asses about the patient health and treatment. There are various imaging tools available that provide scans of different parts of the body including x-ray, CT scan, MRI and others. Often, the images obtained through the imaging tools contain image noise or distortion generated through the device or imbalance light exposure, resulting in problems for the practitioners to have optimal opinion about the disease and its cure. Image enhancement tools and technologies help greatly in this regard to improve the features of the image for best analysis.

Noise suppression in medical imaging is an interesting and great challenge to pay attention. The image noise obstacles the image analyst to interpret the image information for robust analysis [1]. Several approaches have been proposed in literature to suppress the image noise. Kutluk Han Uslu et al. [1] proposed Split Spectrum Processing (SSP) technique for medical images enhancement. The authors observed that certain such algorithms could be modified for medical imaging (those having scattered and absorption characteristics). SSP technique is based over frequency diversity concept and can be used for noise suppression and flaw detection. The authors found it better as compared with linear frequency diversity techniques. Similarly, Wei Qian et al. [2] proposed an adaptive multistage nonlinear filter used in conjunction with wavelet transforms for image enhancement. The authors used wavelet transforms for noise suppression and multi-resolution analysis. Contrary to the traditional approaches e.g. edge detection, wavelet enhancement methods based on Gabor wavelet transforms and Gaussian envelope functions, the authors' proposed filter enhanced by decomposition and reconstruction processes. The hybrid filter selectively combined the filtered and reconstructed images containing feature of interest with background which aims to enhance the specific areas in image. Rashmi Muthy et al. [3] used scaling techniques for medical image enhancement. The frequency diversity techniques were analyzed as outperforming over reconstructed images. These concepts brought better results than common image decomposition and reconstruction wavelet transforms with a quadratic filter bank. Different scales were chosen to exhibit high target localization energy. The reconstructed images at scale 1 provided the enhancement but image contrast was not achieved. Giuseppe Boccignone et al. [4] proposed multi-scale contrast enhancement methodology for image enhancement. The authors applied various contrast enhancement methods such as classical histogram specification, local and wavelet based techniques and proposed multiscale enhancement to compare the results. The method was aimed to overcome the limits of classical techniques and encompassing the advantages of multi-resolution approaches. The authors assumed that optimal local contrast is the contrast computed at local scale among multiple scales. A nonlinear scale space is generated to design an edge sensitive contrast enhancement. The experiments were performed over Histogram specification, locally adaptive contrast enhancement, Wavelet based multiscale edge representation and decomposition scales (scale adaptive stretching function). In the same way, Wei Ping et al. [13] proposed a multiscale image enhancement method based on fuzzy logic. Chang-Shing Lee et al. [5] proposed a system PACS (picture archiving and communication system) which was based over fuzzy technique to process medical images. The system consisted of image acquisition, storage and display of subsystems that were integrated by digital networks. The fuzzy logic was combined with knowledge based for boundary detection in image enhancement. Katsuya Kondo et al. [6] proposed a complex values CNN filter for medical image enhancement. The technique used a cellular neural network filter with complex weighting factors which improved the signal to noise ratio and processed the two dimensional analytic signals of input images. The filter parameters were determined by application of complex domain back propagation algorithm. The authors observed outperformance of filter as robust and noise tolerant for medical images. Du-Yih et al. [7] used wavelet transforms for medical image enhancement. The author developed a transformer function that was derived by transferring coefficients at different multi-resolution levels with various weighting values. It was observed that wavelet filter generated more accurate results as compared with traditional Fourier transforms based methods. Ioannis Stephanakis et al. [8] developed a fuzzy model for segment dependent local equalization for enhancement. Histogram equalization was performed over image segments. A Gacsadi et al. [9] proposed a cellular neural network method by adopting linear template of 3x3 grid. The CNN analogous to non-linear processors depicted greater enhancement than traditional approaches. In the same way, He Qing-hang et al. [10] devised a way for processing degraded medical images. A combined method was applied to reduce the image noise. LC. Zhang et al. and Svensson et al. [11-12] proposed adaptive pyramid filtering for image enhancement. A log-compressed speckle image is decomposed into multi resolution representations, and then each layer is filtered with adaptive filter. Li Ke et al. [15] proposed a human visual characteristic model that distinguished gray scale and sensitivity to the structure of the image. The image could be divided into areas and detailed areas and processing techniques were used in processing.

2. Material and Methods

We have proposed an integrated approach based over noise suppression and feature enhancement using wavelet filter and prewitt operator. The enhancement methodology can be described as,

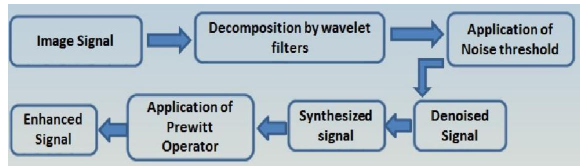

Figure 1 Proposed Methodology

Figure 1 depicts the major steps in the proposed methodology for image signal enhancement. The image signal is decomposed by wavelet filters, a soft noise threshold is applied to the high frequency components of decomposition, the denoised signal is synthesized and prewitt operator is applied which further enhances the features of image.

The image signal is denoised subjected to 3rd order decomposition and synthesis by Db3 transforms.

$$
\begin{aligned}
s(t) &= P_1(t)+Q_1(t) \\
&= \sum_l gP_2(l)\varphi_{f-2,l}(t)+\sum_l gQ_2(l)w_{f-2,l}(t)+\sum_l gQ_1(l)w_{f-1,l}(t) \\
&= \sum_l gP_3(l)\varphi_{f-3,l}(t)+\sum_l gQ_3(l)w_{f-3,l}(t)+\sum_l gQ_2(l)w_{f-2,l}(t)+\sum_l gQ_1(l)w_{f-1,l}(t)
\end{aligned}
$$

Where s(t) represents the digital signal and P and Q are approximate and detail factors information respectively. The decomposition is addressed by transforming the signal into low-pass and high-pass digital filters. The low frequency components of the signal are separated, while high-pass components are further passed through a second order wavelet filter. This second level decomposition results in series of low and high frequency fragments. The high frequency components are again sampled for third level decomposition which creates another buffer of high-pass components.

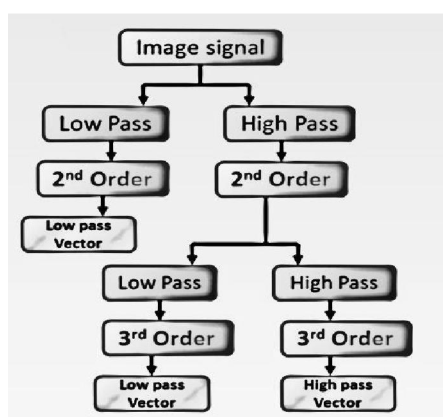

Figure 2 Application of wavelet filter of 3rd order

Figure 2 shows the decomposition of image signal in a series of low-pass and high-pass components. 3rd level decomposition further decomposes high scale components.

Since the 3rd level decomposition has been performed, the signal noise is contained in the high frequency components of the signal. The wavelet coefficients obtained after decomposition are treated with the fixed noise threshold to suppress noise. Since soft threshold commonly smooth the signal and suppresses the noise, we also observed the soft threshold suitable for removing noise from high frequency components.

The decomposed signal after application of threshold is synthesized for its approximate and detail coefficients. This process is carried out by up-sampling the signal. Mathematically, the up-sampling can be stated as,

$$S1(n) = \sum_{l} gX_1(l)a_1(n-2l)$$

$$S2(n) = \sum_{l} gY_1(l)b_0(n-2k)$$

S1 and S2 represent the vectors containing up-sampled coefficients in synthesis process. The low-pass and high-pass components are up-sampled with short and high range filters to produce refined components of signal.

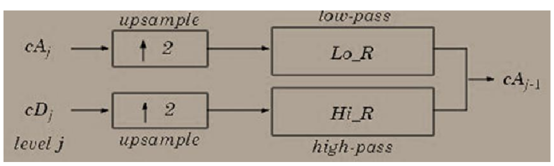

Figure 3 Signal syntheses after application of noise threshold

Figure 3 shows an up-sampling of approximate and detail coefficients. The up sampled signal vector contains the smooth denoised signal. Since prewitt operator provides uniform smoothing in one direction with edge detection in the perpendicular direction, we have employed this operator for further feature extraction. Prewitt operator consists of a pair of 3×3 convolution masks, assigning similar weights to all the neighbors of the candidate pixel whose edge strength is being calculated. One mask is simply the other rotated by 90°.

-1	-1	-1
0	0	0
1	1	1

f_x

-1	0	1
-1	0	1
-1	0	1

f_y

Figure 4 Prewitt convolution masks

These masks are designed to respond to edges running horizontally and vertically relative to the pixel grid, one mask for each of the two perpendicular orientations. The masks can be applied separately to the input image, to produce separate measurements of the gradient component in each orientation (call these fx and fy). These can then be combined together to find the absolute magnitude of the gradient at each point and the orientation of that gradient. The gradient magnitude is given by:

$$|\nabla f(x,y)| = \sqrt{f_x^{\,2} + f_y^{\,2}}$$

Using the mask, as shown in Figure 4, the approximate gradient magnitude is computed using:

$$\begin{aligned} |\nabla f(x,y)| &= |f_x| + |f_y| \\ &= |(\mathbf{P}_7 + \mathbf{P}_8 + \mathbf{P}_9) - (\mathbf{P}_1 + \mathbf{P}_2 + \mathbf{P}_3)| + \\ &\quad |(\mathbf{P}_3 + \mathbf{P}_6 + \mathbf{P}_9) - (\mathbf{P}_1 + \mathbf{P}_4 + \mathbf{P}_7)|, \end{aligned}$$

This is much faster to compute,

$\mathbf{P}_1$	$\mathbf{P}_2$	$\mathbf{P}_3$
$\mathbf{P}_4$	$\mathbf{P}_5$	$\mathbf{P}_6$
$\mathbf{P}_7$	$\mathbf{P}_8$	$\mathbf{P}_9$

Figure 5 Neighborhood pixels for a 3×3 Prewitt mask

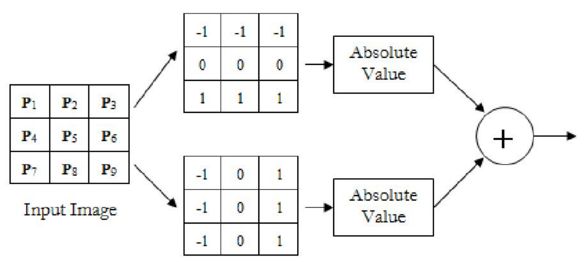

Figure 6 Magnitude of the gradient of Prewitt filter

The angle of orientation of the edge is given by:

$$\theta = \tan^{-1}\left(\frac{f_x}{f_y}\right) - 3\pi / 4$$

Figures 5 and 6 describe neighborhood pixels and gradient's magnitude of prewitt operator. Window of prewitt operator has been convoluted with the signal with application of zero padding. signal is padded and convoluted with a Window fucntions for generation of segments. Initially, the signal was segmented into sections, suppose L being the length of signal and W as window length. The signal is padded from left and right sides to get the uniform sized segments in a way that equally divides window size to the length of signal at these sections.

3. Results

We have applied the proposed methodology to wide range of variant image datasets including MRI and CT-Scan images. A summarized anlaysis has been presented here,

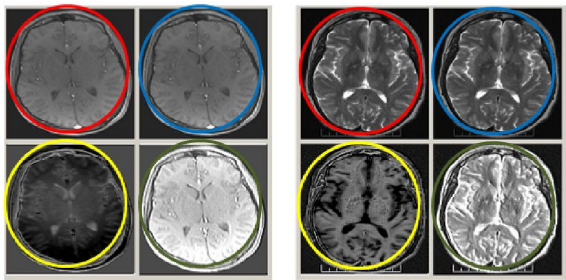

Figure 6 Comaprative analysis of results for MRI brain images (First Set)

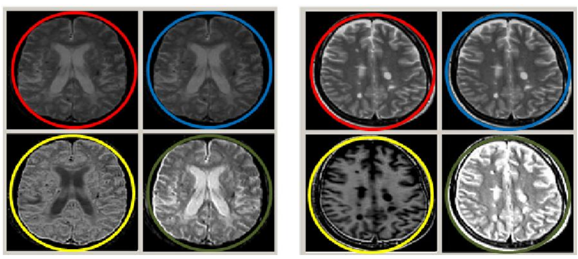

Figure 7 Comaprative analysis of results for MRI brain images (Second Set)

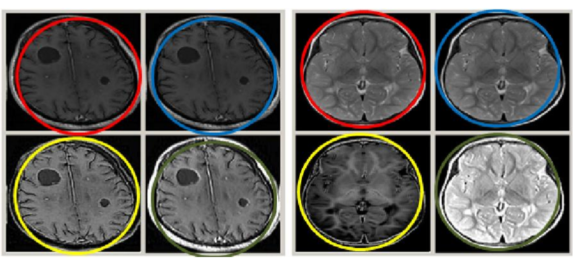

Figure 8 Comaprative analysis of results for MRI brain images (Third Set)

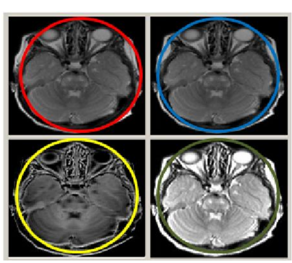

Figure 9 Comaprative analysis of results for MRI brain images (4th Set)

Figures 6-9 depict four sets of MRI image of brain analyzed for enhacement. The iamge represented with red circle is the origianl image, images represented with blue and yellow circles have been shown expoliting image analysis techniques based over guassian (call it as method 1) and laplacian (call it as method 2) transformations for image enhacement.

4. Discussions

The image shown in previous results with green circle has been enhanced usign proposed image enhacement approach. A notable enhancemnet can be noticed for the enhanced approach.

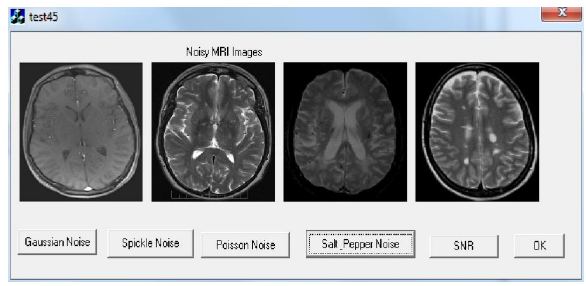

Figure 10 Calculations and comparative analysis of different image noises

Further, we have calculated different image noises i.e. Guassian, Spicke, Poisson and Salt and Pepper noises and compared them with image to noise ratio of proposed approach. A significant SNR (signal to noise ratio) was observed as comapred with prevailing solutions based ver image conventioal transformations.

	Gaussian	Speckle	Poison	Salt & Pepper
Method 1	42.01	31.86	39.62	58.07
Method 2	36.43	26.28	34.04	52.49
Enhanced Approach	58.43	48.28	56.04	74.49

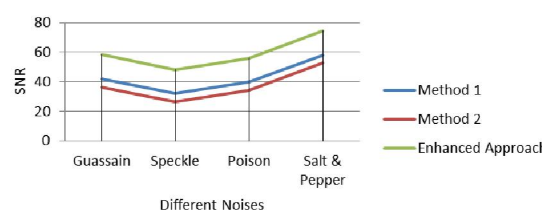

Figure 11 Comparative analysis of prevailing methods with the enhanced approach

Figure 11 presents a comparative analysis of prevailing approaches with the enhanced approach in terms of signal to noise ratio calculated for different noises. It can be observed that proposed apprach owns a significant value of SNR as comapred with other existing solutions.

5. Conclusion

This paper presents an integrated approach for medical image enhancement based over digital wavelet filter and prewitt image filtering approach. Our methodology includes transformation of RGB image to a gray scale image, filtration of image using low pass and high pass band discrete filters of third order, application of soft threshold factor over decomposed wavelet coefficients, synthesis of noise-reduced decomposed signal and application of prewitt filtering method for further suppression of noise and enhancement in features of image. We observed that integration of wavelet filter with prewitt filter greatly helped in uniform smoothing of signal in one direction and edge detection in other direction. The target smoothed noise suppressed image outperformed for a significant percentage of improvement by bringing better results over traditional image enhancement techniques. The authors are ambitious to propose new wavelet functions based on dyadic de-noising filters with suitable threshold factors to suppress the signal noise as an imminent anticipation.

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Corresponding Author:
Muneer Ahmad,
College of Computer Sciences,
King Faisal University,
Saudi Arabia.
E-mail: mmalik@kfu.edu.sa

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