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Medical Image Enhancement using Fuzzy and Regression based Neural Network Approach

L. Shyam Sundar Singh[1], Dr. Anil K Ahlawat [2], Dr. Kh. Manglem Singh[3], Dr. T. Romen Singh[4], Y. Subhaschandra Singh[5]

[1] *Research Scholar, Computer Science Department, Mewar University, Gangrar, Chittorgarh, Rajasthan, India.*

[2] *Department of Computer Application, Krishna Institute of Engineering and Technology, Ghaziabad, UP, Meerut Road, India.*

[3] *Department of Computer Science and Engineering, NIT, Manipur, Imphal, India.*

[4] *Department of Computer Science, Manipur University, Imphal, Manipur, India.*

[5] *National Institute of Electronics and Information Technology, Akampat, Imphal, Manipur, India.*

Abstract

The basic purpose of the image enhancement is digitally manipulating the image to improve the quality of the image. It is found to be the simplest division of the medical image processing and is used to extract the required portion of the image. This proposed paper presents a neural based fuzzy enhancement technique. The pre-processing of the images is performed by the wiener filter and the contrast enhancement is obtained by the local transform histogram (LTH). The enhanced image obtained is given to neural based fuzzy enhancement which performs the process in three steps such as fuzzification, membership function and defuzzification. The evaluated parameters such as PSNR (peak signal to noise ratio) and CNR (Contrast to noise ratio) of the proposed technique are compared with different types of result images of different methods and it is found that the proposed method has highest PSNR value.

Keywords: Image enhancement, PSNR, CNR, contrast image, Neural based fuzzy.

1 INTRODUCTION

Medical imaging field is becoming important nowadays for diagnostic and treatment use. It is one of the complex fields and consists of experts and expertise in different fields and uses various equipment for diagnosis of disease such as Magnetic Resonance Imaging (MRI), Positron Emission Tomography and Computed Tomography etc. The role of the medical imaging is totally crossing the disciplines of Computer Science, Electrical Engineering, Electronics Engineering [2]. The imaging details present in disease diagnosis always affects the results of the diagnosis. The information loss which occurs when the image is captured and thus decreasing the contrast of the image. The dilemma present in the image is in the form of Gray levels, contrast of the image and the background thereby makes it difficult to segment or detect the boundaries of the blood vessels present in the image [3]. The main objective or aim of the image enhancement is to smooth an image with considering non-impulsive noise. Linear filters are used for the noise reduction, segmentation [4]. To display the low contrast images and blurred ones it is necessary to take enhancement processing to medical images [5]. The increase in the contrast of the image is more useful to recognize the inaccurate diagnosis of the disease. This helps in transforming the image to another form which is more appropriate. The aim of the image enhancement techniques is to improve the quality and the visual appearance of the image to the human viewer by manipulating the existing image. The low contrast image is inconvenient for human visualization and hence image enhancement is one of the most challenging, interesting and important area of research in image processing. The different types of image enhancement methods such as global [6, 7], local [8, 9] and hybrid [10] etc are used to solve the complex problems in the image visualization, data retrieval of the diagnosed disease and statistics many algorithms are developed. Many imaging techniques are also available such as computed tomography, Magnetic resonance imaging, Mammography and others. MRI is a kind of multi-planar technique which helps to capture the images of sagittal, coronal planes without disturbing the patient to obtain the images of the internal structure of the body. The medical data is not solely regarding medical images but also contains the medical reports which is unstructured text. As long as the medical images contain the uncertainties the fuzzy methods are useful. Researchers applied different fuzzy approaches [11, 12] in image enhancement techniques based on the type of image domains. Nowadays, medical imaging is very common and essential media for medical professionals for diagnosis of diseases regarding unseen regions inside the body. The traditional technology used in medical image enhancement also includes Gray transform method and histogram equalization method [13]. Existing histogram equalization method makes the probability distribution Gray level images to uniform probability distribution images using a transform such that information entropy of the image is largest [14]. Histogram equalization usually enhances the contrast of many images especially when the image data is represented by contrast values. The process of image enhancement methods is briefed as the methods which generally process the whole image and collects the local information and interference by the noise that occurs makes medical image processing quite difficult. The medical enhancement images based on the 2D EMD (Empirical mode decomposition) will mainly concentrate on image details features and acquires the characteristics of the original image data information effectively. There are numerous mathematical tools which deals with the uncertainties [5]. The fuzzy set which considers the uncertainty in the form of membership function is also explained [15]. To modify the membership and to enhance the contrast of the image the most used operator INT operator is considered [16]. Neural networks are well known

for the performance in image enhancement techniques and is used in medical image enhancement specifically from past many years. Fuzzy rule-based techniques are also very powerful and nowadays it has become a common technique for enhancement of images. In this proposed technique also, fuzzy membership function technique is applied to detect edges within the image and applied different enhancement functions on edge and non-edge area within the image itself.

2 RELATED WORK

Roy et al., [17] proposed automatic brain tumour detection approach using symmetry analysis. The approach has multi step to solve the complex MRI segmentation problem. The researcher said that the MRI segmentation is important task in the medical area and consumes more time if it is performed manually. So visually study of the MRI is more suitable and also fast. Chaudhari et al., [18] proposed an efficient method for brain tumour detection. The mean shift and normalized cut algorithm are performed to detect the brain tumour surface area in MRI. Logeswari et al., [19] describes the segmentation method which has two phases. The first phase has MRI brain image which is collected from the patient's database and Hierarchical self-organizing map is applied in the next phase for segmentation.

Khurana et al., [20] proposed a brain tumour segmentation technique and validated the image segmentation on 2D MRI data. The tumour which is present is segmented and the parameters are set appropriately. The fuzzy C means clustering approach is used with MAP neural network along with the proper classification of the medical data. The first phase is to calculate the area of the tumour of single slice of the MRI data set and then the area of the tumour from multiple image MRI data set is calculated. The evaluation results show that the fuzzy clustering classification can easily segment a tumour and the approach is having better performance compared with the other approaches. This work shows that the methods aimed at general purpose segmentation tools in medical imaging is used for the automatic segmentation of the brain. The limitation is that the method used is semi-automatic. The future work is carried out to make the method automatic which computes the dimensions of the segmented tumour.

Raghtate et al., [21] proposed fuzzy interference system for brain MR image enhancement. The fuzzy image enhancement is based on the Gray level mapping into a fuzzy plane using a membership function. The comparison of the enhancement performance between the median filter and fuzzy interference system is made. The methods are tested on 15 brain images and the comparison is based on the parameter peak signal to noise ratio (PSNR). The results evaluated shows that the fuzzy interference system is able to get the contrasted image which automatically increases the brightness and improves the contrast of the low contrasted images. The noise discrimination is achieved and enhances the quality of the image to a great extent. The comparison values show that the fuzzy interference system improves the enhancement quality of MRI brain images over the median filter with improved image appearance. The noise with high contrast MRI is removed from MRI brain images.

G. Raju et al., [22] have presented a new fuzzy and histogram-based method to enhance the low contrast colour images. The proposed method is fast as compared to other enhancement techniques. The fuzzy method has RGB image which is converted to the HSV (hue, saturation, value) colour space to preserve the H and S components in the image. The control parameters such as M and K have been used and v component is stretched. The main motto of the method is to convert the histogram of original image into a uniform histogram. The fuzzy based method shows better results than the traditional methods such as histogram equalization, Bi-histogram equalization and Gray level grouping on the basis of the visual quality.

3 RESEARCH METHODOLOGY

In this research, Neural Fuzzy based Technique (NFT) along with wiener filter and local transformation histogram process is used for noise removal and enhancement of the quality of the input image. In general, the input image comprises with noisy factors due to the variations in the intensity and the output image is found to be critical to analyse certain vital information regarding diseases. The above mentioned limitations are minimized through the proposed technique by deploying noise enhancement, contrast enhancement and image enhancement through this process. The detailed description and the workflow of the proposed methodology is explained in the following stages,

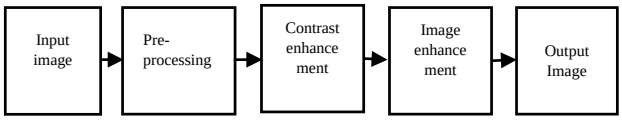


Fig 1: Block Diagram of the Proposed System

The block diagram of the proposed system is shown in Fig 1. At the initial stage, the input image obtained is processed through the designed wiener filter to remove the presence of noise parameters in the image. Later, pre-processed image in forwarded to local transformation histogram technique for contrast enhancement. This process plays an important role to enhance the quality of the information that is present within the minimal dynamic range of the pre-processed image. Neural fuzzy based technique is employed at the end stage to enhance the quality of the input image and to achieve better results with high precision to analyse the results or used for future analysis. The detailed description of the individual stage and its working principle is explained in the following subsections.

3.1 Input image

The input image comprising details regarding the human brain is extracted from the medical database. Several samples are obtained for the analysis and to evaluate the system in terms of enhancement capability. This image is considered as "A" sample of size $x*y$ with grey level of range G_{min} *to* G_{max} and the same can be designed in the form of array with fuzzy singletons. Individual element in the array matrix represents the

membership value and the degree of the brightness in the image can be written in the fuzzy set notation given by,

$$\mu_{mn} = \frac{(A_{mn} - A_{min})}{(A_{max} - A_{\min})} \quad (1)$$

Where,

μ_{mn} = Degree of brightness of the image

A_{mn}= Grey level intensity of the image

m*n = Image pixel representation

The main goal of the proposed research is to remove the noise present in the input image and to enhance the quality. After the calculation and representation of input image in the form as shown in equation 2, it is processed through wiener based filter for pre-processing and removal of noise.

3.2 Pre-processing through wiener filter

Wiener filtering process is an advanced optimal based technique used for removing the noise from the input image. The main intention of employing is to reduce the overall mean square error through inverse filtering technique and noise smoothing. This process can be achieved with linear estimation of the original input image through stochastic framework. By employing orthogonality filter in the process, the wiener filter can be expressed in terms of Fourier Transformation given by,

$$W(F_1, F_2) = \frac{H*(F_1,F_2)\, S_{XX}(F_1,\ F_2)}{|H((F_1,F_2)|^2 S_{XX}(F_1,\ F_2) + S_{nn}(F_1,\ F_2)} \quad (2)$$

Where,

$S_{XX}(F_1,\ F_2) + S_{nn}(F_1,\ F_2)$ = Power spectra of the original input image and the noise factor

$H * (F_1, F_2)$ = Blurring filter

During the analysis, the process is divided into two parts namely inverse filtering process and the smoothing part of the noise.

Initially, during the deployment of wiener filter, the original the power spectre parameter is estimated along with the presence of additive noise. In the presence of white additive power noise, variability observed in the noise is equal to the power spectrum. Periodogram estimation process is employed in this research to calculate the estimated value of power spectrum and the equation for the same is given by,

$$S_{yy}^{p} = \frac{1}{N^2}[Y(k,l)Y(k,l)^*] \quad (3)$$

Where,

$Y(k,l)$ = DFT obtained from the observation

It is seen that the proposed noise filtering technique can be easily implemented without concerning about the inverse filtering singularity. The power estimation S_{yy} can be directly calculated through the observation from the periodic estimate and it is given by,

$$W = \frac{1}{H}\frac{S_{yy}^{P} - S_{nn}}{S_{yy}^{P}} \quad (4)$$

Where, W represents the denoised output image after processing through wiener filter. The denoised image is further processed through local transformation based histogram technique for contrast enhancement of the particular region in the image.

3.3 Local Transformation based Histogram Technique

The key process of image processing is image contrast enhancement. In medical image analysis, reproducing the image with better contrast and high quality is essential to detect the diseases. Contrast enhancement will minimize the problem arise due to the unnatural contrast present in the input image and is used to study all the hidden information present in the captured image. In this research, we are employing histogram based local transformation technique for contrast enhancement.

A novel method comprising local transformation along with histogram equalization are the two generally used methods for global contrast enhancement. This techniques are dependent on the global information of the image. Local transformation can be achieved by enhancing the grey values of the input image and adjusting the dynamic range of the image. Later, input mapping co-ordination is achieved through the integral of histogram image.

The histogram technique is found to be a most promising technique in image contrast enhancement. The grey level pixels present in the image is redistributed with respect to the probability distribution. Global histogram technique is a process of global enhancement of the image and found to be effective for medical image diagnosis and representation. In this method, the undesired effect caused due to the over emphasizing noise as the image pixel with high frequency and grey level rules over the low frequency part of the image will be analysed. The transformation function is employed to enhance the quality of the image.

Local histogram equalization technique is an advancement of global based technique, is deployed in this research and it works on the basis of block processing. The pixels required for the enhancement is selected in the form of blocks or window size and only those windows will be processed for image enhancement.

The local histogram is categorized into two parts, first part is through the local window and the other is through the histogram obtained outside the window. The equation for the same is given by,

$$h_L(R) = \alpha h_w(r) + (1+\alpha)h_B(r) \quad (5)$$

Where,

h_w = Normal histogram captured of the selected window

h_B = Remaining normalized histogram portion in the image

The value α will be defined within the limits 0 to 1. The equation for α is given by

$$\alpha = \frac{A_w}{A_B} \quad (6)$$

Where, A_w and A_B represents the image area in pixel of region *W* and *B.*

Through this process, the value of α can be adjusted to obtain efficient local histogram simulation and its influence on the surrounding ROI. From output obtained, it is seen that all the local histograms comprises with similar grey values as of global histogram but variation in their amplitude at individual grey level at different positions. After enhancing the contrast of the selected window, the image is further processed through neural based fuzzy technique for image enhancement.

3.4 Image enhancement through Neural based Fuzzy Technique

Neural based Fuzzy Technique (NFT) is a combined approach of Artificial Neural Networks (ANN) and Fuzzy systems. ANN approach is used to determine the typical properties of data samples and fuzzy based technique which is used to determine the uncertainty in the input image. In general, the neural based systems is defined as a system in which fuzzy based rules are employed and the particular sets are adjusted through the neural network techniques through an iterative process. Initially, the developed system acts as neural network where the learning of critical parameters takes place and converted into fuzzy systems during the time of execution. Co-operative based neural network model is employed in this research in which it works as pre-processor. Through this process, the fuzzy based interference system or fuzzy rules are being employed to calculate the membership function and artificial learning mechanism for training the data. The work process of the individual algorithm is explained in the following stages.

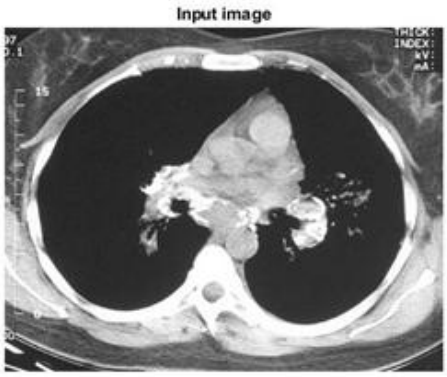
3.4.1 Artificial Neural Network (ANN)

Artificial Neutral Network (ANN) is a technical process in which analysis is achieved through the computational model and simulation is done through the functional aspects of biological based neural network. The process of ANN comprises with a human based learning capability and individual network captures the knowledge through a set of neurons and learning process. The knowledge captured is then stored in the form of internal parameters known as weights and then the same is used to find the patterns in the data.

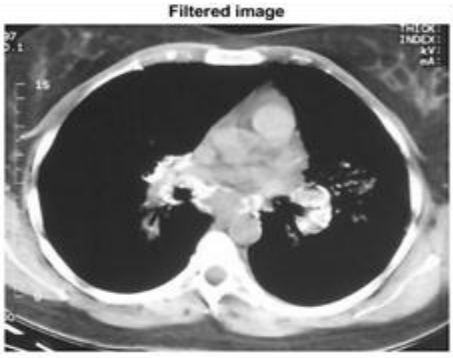
3.4.2 Fuzzy Logic Systems

In fuzzy logic based image processing techniques, fuzzy sets are employed to define the entire approach and is used to understand, define, represent and process the input images, segment them and extract the efficient features. It has a special feature of human like reasoning capability in which the image features are represented in the form of linguistic variables and then fuzzy if then rules are employed for segmenting the image. It comprises with three stages namely image fuzzification, modification of membership value and image defuzzification.

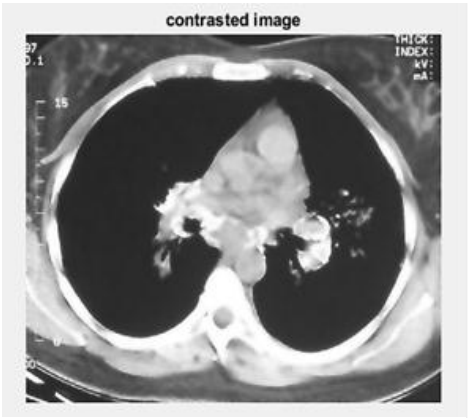
Figure 2 shows the input image and corresponding result of the individual associated stages which are involved in this proposed system.



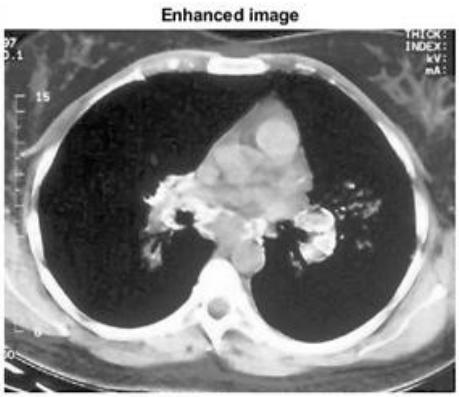
a. Input brain image considered for analysis



b. Filtered output of the input image



c. Output contrasted image after denoising



d. Enhanced final output image

Fig 2: Output image obtained from the analysis

4 RESULTS AND DISCUSSION

In this research, NSL based image processing technique is developed for medical image processing along with wiener filter for image pre-processing and local transformation based histogram technique for image contrast enhancement. The program for the proposed system is written through MATLAB supported language and implemented using MATLAB R2017b software. Furthermore, the proposed system are calculated through the following metrics to evaluate the effectiveness and quality of the output image and they are as follows,

Mean Square Error (MSE): Mean Square Error is the average squared difference between the estimated values and what is estimated. It can be applied in image quality evaluation of an image of size $m \times n$ as

$$MSE = \frac{1}{m \times n} \sum_{i=1}^{m} \sum_{j=1}^{n} |x - \bar{x}|^2 \qquad (7)$$

Where x represents the input image pixel and $\bar{x}$ the average of the input image respectively.

Peak signal-to-noise ratio (PSNR): It is defined to calculate ratio amongst the maximum possible signal power of a signal that can be achieved and the corrupting noise power which affects the fidelity of its representation. PSNR value will be usually represented in the form of logarithmic scale due to the wide dynamic range of input signals and it is given by,

$$PSNR = 20log_{10}\left(\frac{Max_f}{\sqrt{MSE}}\right) \qquad (8)$$

Where,

Max_f = The maximum signal value obtained for the original input image

The output images captured from the proposed system after processing through individual stages are shown in Fig 2. Initially, the input image as in Fig 2(a), is processed through wiener filter to reduce factors present in the input image and produce as result denoised image as shown in Fig 2(b). Further, the denoised image is further processed through local transformation based histogram technique for enhancing the required portion of the image and the same is shown in Fig 2(c). After processing through NSL technique, the enhanced output obtained through the analysis is shown in Fig 2(d) as the final result.

The proposed technique is implemented on three different image types say Medical Image, Fingerprint Image and Selenography Image. Visual results are demonstrated in Fig 3 to Fig 5, respectively by comparing with other techniques like Equalized Histogram Equalization Image Enhancement Method (EHE)[1], Histogram Matching Image Enhancement Method (HS)[1], and Histogram Equalization Image Enhancement Method (HE)[1]. It is difficult to compare the enhancement results by visual appearance and just looking at the images with naked eye only. Hence, it is also required to compare the result by measuring the result quality through suitable metrics. This paper used Peak Signal to Noise Ratio (PSNR) and Mean Squared Error (MSE) as quality measuring metrics. The golden rule is that the higher the PSNR, the better noisy images has been enhanced and the better the enhancement algorithm. This would occur when we minimize the MSE between the images with respect to the maximum signal value of the image. Table 1 shows the corresponding metrics of the results as shown in Fig 3 to Fig 5. From the experimental results, we observed that this proposed technique outperforms.

a. Input b. EHE c. HS

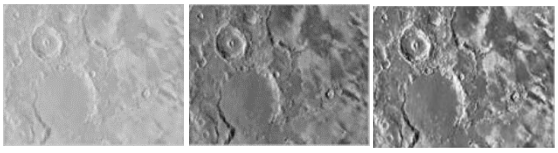
d. HE e. Proposed

Fig 3: MRI output image comparison of different techniques

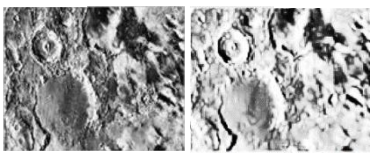
a. Input b. EHE c. HS

d. HE e. Proposed

Fig 4: Finger print output image comparison of different techniques



a. Input b. EHE c. HS



d. HE e. Proposed

Fig 5: Selenography output image comparison of different techniques

Table 1: Performance metric calculated in terms of PSNR and MSE value

Image Type	Method	PSNR	MSE
MR Image	**Proposed**	**32.96**	**20.04**
	EHE	31.75	43.43
	HS	30.33	60.1563
	HE	19.9431	658.8181
Finger Print Image	**Proposed**	**19.82**	**57.99**
	EHE	19.66	702.59
	HS	19.16	788.55
	HE	18.58	902.16
Selenography Image	**Proposed**	**25.41**	**58.32**
	EHE	12.28	3842.60
	HS	11.18	4952.00
	HE	10.74	5487.10

CONCLUSION

Image enhancement is a key process in digital image processing and improving the quality of the input image. Several techniques has been presented for image processing, but it is seen that the existing technique only improves the visual appearance by suppressing the other portions of the input image. In this research, a novel technique is developed for input image processing and transformation technique is employed for segmenting the required part of the image. The findings obtained from the analysis shows that the proposed method gives better results compared to other existing techniques. Also it is seen that the proposed technique does not suffer with the over enhancement problem which is seen in the existing techniques. In this research, the application is limited for only certain images, but in future the technique can be implemented to other applications such as key frame extraction of videos and so on.

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