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Deep Learning and Fuzzy Logic Based Intelligent Technique for the Image Enhancement and Edge Detection Framework

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ABSTRACT

Medical imaging is the promising area in digital image processing. Medical images are useful for all types of medical treatment and diagnostics. Medical images are captured through the medical devices, consists some kind of noises and it requires efficient enhancement techniques. Medical imaging also useful in the image segmentation and object detection purposes. Various researcher proposed several types of enhancement techniques and edge detection techniques, but still accuracy and noise are challenge for the enhanced image. So, it is the need of some intelligent techniques to address these issues. In this work we proposed deep learning-based convolution neural network for the image denoising and image enhancement and for the edge detection fuzzy logic-based approach used. The model of DnCNN used here for the image denoising and image enhancement, this model comprises several convolution layers along with input and output layer, this model learns according to the weights and bias. Also, fuzzy logic technique implemented fuzzy inference rules which can give more accurate edges of the image. The result obtained through this hybrid approach is very interesting and effective as compare with previous approaches like histogram-based approach and linear filtering approach. Proposed methods give the promising results as compare with existing methods. All types of simulation performed in MATLAB 2020.

1. INTRODUCTION

Image processing has new edge of computing, which uses for in various fields like medical, satellite fields and many more areas. Image processing includes various steps as image acquisition, image enhancement, image restoration, image segmentation, object detection and many more. Image enhancement plays a very crucial role in image processing due to the resultant image after image acquisition phase not useful for further processing. Image enhancement gives proper resolution and good quality image for the different areas [1].

Medical Image enhancement gives a new edge in medical industry. Healthcare industry now converted into smart healthcare where every medical equipment uses latest trends for computing purposes. Medical images are very useful in disease diagnostic and asymptotic treatment. According to the definitions: Black and white images and color images. Both types of images use in medical fields for diagnostic and disease detection purposes.

Medical image enhancement and edge detection system is very important in medical fields. Both approaches have used in various disease detection and treatment purposes. Images obtained from cameras and other devices were not very useful for the perspective of accuracy and result, so image enhancement includes methodologies and techniques to provide the better quality of image in terms of resolution, contrast and brightness. In today every healthcare system includes all facilities for medical treatment and also update it wherever it is required, now X-RAY, Ultrasound, MRI and PET-SCAN have major demanding area where medical industry relies [2].

X-RAY and MRI acquisition systems are constantly improving, yet there are still significant representational uncertainties in the radiographs that are produced. Any margin of error in the realm of medical image analysis is unacceptable.

The volume, quality, and clarity of the visual details are also crucial. Researchers offered numerous image enhancement methods to enhance the quality of the seen image in order to satisfy these objectives. Digital radiographs feature complicated structures and a variety of modalities, unlike traditional still pictures. In order to avoid data loss and to recover the attenuated information, certain manipulations are needed when analysing and processing them.

Many approaches already proposed by various researchers for the image enhancement. Edge detection approaches also useful for the detection of boundaries which is helpful in disease detection purposes like cancer and tumor etc. The foundational algorithm for many spatial domain processing is the image histogram. It offers helpful image statistics and can be used to segment, compress, and improve images. In software and even in hardware implementations, it is straightforward to calculate. Histogram Equalization (HE) creates a complete image with intensity levels that are equally likely [3].

In this research work hybrid methodology introduced here for image enhancement and edge detection purposes. This technique based on intelligent technique uses deep learning-based convolution neural network and fuzzy logic-based inference technique it gives better performance as compare with the previous methods in terms of PSNR, MSE and other various parameters.

This paper organized as Section 2, Related Work which discussed various literature work and related methodologies discovered by various researchers. Section 3 introduced proposed methodology and proposed architecture discussed here. Section 4 covers all the experimental results and discussion and Section 5 conferred Conclusion and Future Scope.

2. RELATED WORK

Many research works carried out in the field of medical image enhancement. Researcher proposes various algorithms for enhancing the quality of the image.

Image Enhancement process carried out to provide the better-quality images for computing purposes. A Very early approach for image enhancement is point based operation. In point-based operation pixel value of each pixel may be modified according to the desired result. Pixel is the smallest element of the image; the value of the pixel directly effects of the image quality.

2.1 Brightness modification

This method calls for the addition of a constant to the existing image. Change the constant's value in accordance with the illustration. We add some fixed or constant value to the image to increase brightness.

$$A(i,\, j) = B(i,\, j) \ + K \quad (1)$$

For reduction in the brightness we should decrease the pixels of the image by subtracting constant value.

$$A(i,j) = \ B(i,j) - K \quad (2)$$

Above Eq. (1) and Eq. (2) shows brightness modification procedure. Where $A(i, j)$ represents the output image, where $B(i, j)$ represents the input image and K is the constant value which changes about the brightness of the image.

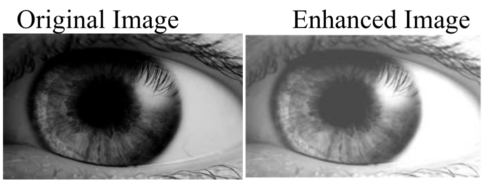

Figure 1. Brightness modification in human eye

Figure 1 shows that image of human eye and also displays the more brighter corresponding image.

2.2 Contrast adjustment

Contrast of the image is also very important factor for improvising the quality of the image. Good contrast images have given the good perception of the image for computing purposes. In contrast adjustment process pixel value of the image can be modified according to the desired result.

$$B(i,\, j) = \ A(i\ ,j)*k \quad (3)$$

Eq. (3) represents the contrast enhancement procedure, in which $B(i, j)$ is the output image, $A(i, j)$ is the input image and k is the constant value which multiplied to the input image.

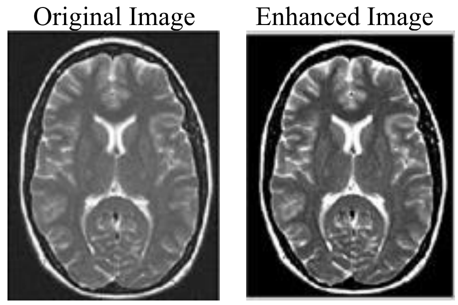

Figure 2. Contrast adjustment in brain tumor image

Figure 2 shows that original image of the brain tumor also displays the contrast displayed brain tumor image.

2.3 Image negative

This approach also useful for identifying the various disease in medical fields. Negative of any image converted complement of the image. XRAY images are the best example of the image negative enhancement process. Image negative achieved through subtraction of the whole image from the maximum pixel value. This process also termed as inverse transformation.

$$B(i,\, j) = 255 \ - A(i,\, j) \quad (4)$$

Eq. (4) represents the negative or inverse transformation procedure, in which the original image $A(i, j)$ subtracted from 255 and output image represented by $B(i, j)$.

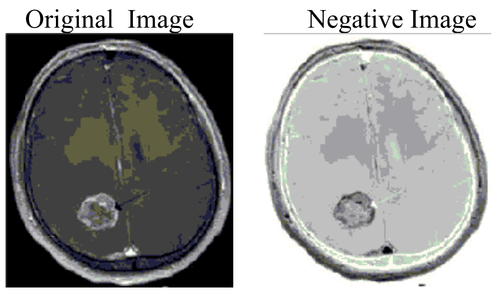

Figure 3. Contrast adjustment in brain tumor image

Figure 3 shows that original image of the brain tumor also displays the negative image of brain tumor.

2.4 Histogram based approach

Point based approaches not suitable for all types of images like low light images and color images as well. It is not always suitable to enhance single pixel for enhancing the whole image. Histogram equalization is also traditional approach working well for visible image. This approach equally distributed the gray scale values to the corresponding image [4]. This approach not suitable for noisy images due over enhancing quality, that is also enhances the noise of the image. Due to this problem some variations in Histogram techniques were introduced.

AHE (Adaptive Histogram Equalization) is the one of the variations in histogram-based enhancement where maximum number of histograms covers all the possible segments. This method works well for all kind of images but suffers to manage contrast.

Another variation in AHE approach is CLAHE which is very specific and limiting contrast of the histogram image. This approach avoids the problems of HE and provide better contrast for the medical images or dark images [5-9].

QDHE (Quadratic dynamic histogram equalization) is also one of the variations in HE, dynamic histogram equalization approach works on quadrant. QDHE preserve the brightness of the image which looks like a natural image [10]. Initial step of QDHE is histogram partitioning divides the histogram into partitions using median partitioning. Then partition the image histogram again if required then clipped the resultant image using the clipping process, clipping process overcome the problems of HE like over enhancement. QDHE controls enhancement rate of the image. After the clipping process the next step is grey level allocation which distributed the gray level to the histograms dynamically and lastly histogram equalization process carried out.

CHE is another variation in HE which is based cumulative distribution function. Firstly, evaluate the histogram of the image and calculate cdf of the image and construct grey value of the image and then replace the grey value of the image with the previous image.

The objective of all the histogram-based approaches to provide better quality image in term of all the qualitative and quantitative analysis like PSNR (Peak Signal to Noise Ratio) and Entropy. Various deep learning-based approaches also proposed by the authors which gives image also denoising the image and increase the resolution of the images. Infrared images have also very noisy and improvement must be required for those types of the images [11].

Also, some of the research work carried out to improve the resolution through recursion. Recursive model improves the performance without introducing some more parameters [12].

2.5 Edge detection in images

Edges are the crucial part of the image, using image enhancement special take care can be consider for the particular edges because at after enhancing process edges may get blur and very difficult to locate boundaries. Edges are the ridges and sharpen boundaries of the image. Edges gives significant contribution towards medical imaging [13].

Many of edge detection filters already proposed by various researchers like Prewit, Sobel, Robert and Canny. All of these filters have very efficient and give accurate results for the desired image [14, 15].

Table 1. Comparison of various edge detection methods

Edge detector.	Method	Performance parameters	Remarks
Robert	Gradient Based	Computation is fast and easy to implement	Sensitive to noise Less reliable
Sobel	Gradient Based	Also fast and easy to implement	Not much accurate result
Prewitt	Gradient Based	Easy to implement and edge detection very well	Sensitive to noise not much accurate
Canny	Guassian Type	Very well for noisy images	Slow response

Table 2. Comparison of various image enhancement techniques

Techniques	Features	Limitations
Spatial domains techniques	Based on point operations, low complexity, used in sharpening and smoothing.	It does not provide the robustness and perceivably.
Frequency domain techniques	Manipulation in Fourier transform, used in changing positioning of image.	It cannot enhance properly every part of the image.
Histogram Equalization	The technique is very simple and efficient.	Not suitable to increase the contrast of the image.
Adaptive Histogram Equalization	Used to recover contrast in images, suitable for improving the local contrast of the image.	It amplifies noise in the image.
Contrast Limited Adaptive Histogram Equalization	It works well when equal division of the images, prevents amplification of noise.	It increases complexity.
BI- Histogram Equalization	It preserves mean brightness.	It has more computation time.
Fuzzy Logic Technique	It is a framework for expert system and neural network.	This method not preserving edges.
Unsharp Masking	Highpass filter is used in this method for enhancement.	It also enhances noise which is presents in noise. It also enhances too much sharpening at edges.
Thresholding transformations	This method is particularly useful for those images which are useful for particular interest.	This method suffers from sensitivity and specificity.
Log Transformation	This technique is suitable for enhancing the dark shade of the image.	Transformation is fixed and not changed as per requirement.
Local Enhancement	This is very simple technique and it is used with neighborhood operations.	This method is not suitable for high contrast images.
Nuro Fuzzy System	In this method neural network used for identification of noise and fuzzy logic used in enhancement purpose.	This method not preserving edges.
Gray level grouping	This method groups the histogram components into proper level of groups according to the amplitude.	The drawback of this approach is that it is not efficient as compare with fuzzy based approach.
Image Fusion	This technique enhances to all regions of the images.	This method is not suitable for weather and foggy images.
AVHEQ (Averaging Histogram Equalization)	This techniques focuses more contrast images.	This method only used for image enhancement not for edge detection.

Some of the author uses wavelets for edged detection in medical images. In medical images X Ray images have a very useful to identify the fracture, still some minute differences not able to detect using naked eyes [16].

As shown in the above Table 1 and Table 2 different previous approaches gives by the various researchers for the image enhancement and edge detection discussed here. Each approach has a different methodology and also suitable remarks mentioned.

All the above discussed approaches work well for the all types of images, and their different domains. In medical imaging 100% accuracy much needed to achieve the good results. These methods still not cover some hidden or unknown factors and uncertainties which is present in the image.

3. PROPOSED METHODOLOGIES

In this paper we introduce some kind of the intelligent techniques for image enhancement and edged detection purposes. Proposed methodology uses deep learning approach.

Deep learning approaches well for all types of images especially medical images. Deep learning is a part of intelligent techniques. Deep learning has a variety of algorithms. CNN (Convolution neural network) is one of famous and efficient algorithms for image enhancement, classification and object detection. We also propose Fuzzy Logic based edged detection method for detecting corners in the image which will further used in image segmentation.

3.1 Convolution neural network

Convolution neural network is a one the famous technique in deep learning, which is very useful for image processing and computer vision applications. In CNN input image supplied to the learner (weights and bias). CNN works intelligently as compare with the traditional approaches. CNN is a special type of a neural network has a multiple layers input layer, hidden layer and output layer. It also addresses the issues of the overfitting of the model.

Image enhancement is used in various fields to recover lost features of degraded images, Medical imaging, film production, autonomous driving, etc. vehicle. This enabled a dramatic improvement in image quality enhancement [17].

CNN very useful for image enhancement and image classification. CNN plays very crucial role in image enhancement. In raw image several types of noises are there, for further processing it is mandatory to remove the noise with images. Medical images captured through various traditional medical equipment; it must present some sort of noise. With the presence of noise and ambiguity it is difficult to identify the symptoms and predicts the diseases.

ResNet gives various transfer learning in image. It provides more deeper architecture for various learning [18].

For the image enhancement purpose the DnCNN (Denoising Convolution neural network) very useful to remove the Gaussian noise present in the images, this model handles the unknown Gaussian noise with unknown noise level. It works on residual learning with the help of several hidden layers and also increase the resolution of the image.

As shown in Figure 4 Denoising CNN consists of multiple convolution layers and ReLU for transfer learning. In each layer model learns according to the weights and bias. Learning may improve from one layer to another layer. Noisy image passed to the CNN and after completing the process, residual image of the corresponding image generated, which will further denoised by the DnCNN [19].

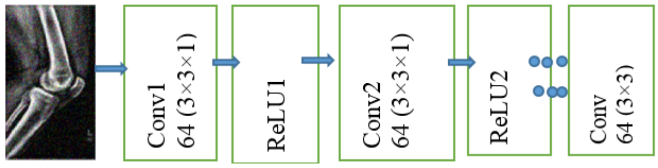

Figure 4. Architecture of DnCNN

In DnCNN whole learning completed by the following phases: Residual Learning where input image passed through the multiple layers and finally residual image was generated. Next is Batch Normalisation where input layer is normalise according to the learning rate due to the variation in the input image features. Normalisation also applied to the hidden layers to solve the problem of overfitting [20].

3.2 Edge detection using fuzzy logic technique

Edges are very crucial in the image processing. Edges are the boundary region between two uniform region of the image. Edge detection is very useful for the image segmentation and object detection. In medical imaging several types of diseases discovered through segmentation and object detection. Image segmentation discovers the interesting portion of the image and study the desired portion of the image like tumor detection and cancer detection in the medical image.

Various methods for edge or corner detection like Prewitt, Sobel and Canny already developed. Due to the crispiness in the uniform regions small differences between the images will be consider for the edge detections. Here we propose fuzzy logic inference mechanism based on the intelligent decision making. Fuzzy logic is the intelligent method works well for the all types of noisy images. Fuzzy deals with all uncertainties and noise level present in the image.

3.2.1 Fuzzy logic reasoning mechanism

Fuzzy logic inference used in many areas of the image processing like image segmentation, object detection. Fuzzy logic included as the input which may fuzzified through the fuzzy mechanism using different membership functions. Here gaussian membership used fuzzy inference system. Some threshold value may be used for satisfying the fuzzy rules. Fuzzy logic properly handles the images because in image processing a boundary between the uniform region is always there. In unform region boundary may not clear to easily detect using the crisp approach. Fuzzy logic identifies the small changes in the intensity levels of the image as well.

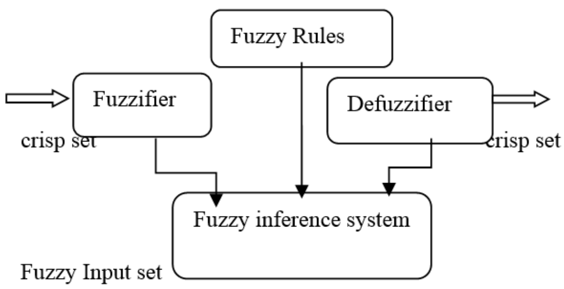

Figure 5. Fuzzy inference system

In Figure 5 fuzzy inference mechanism elaborated in details which include all the necessary blocks for the fuzzy logic-based mechanism. It comprises fuzzifier which convert the crisp or non-fuzzy element into the fuzzy element using Gaussian membership functions. This process completed with the fuzzy reasoning if then rules and the final result obtained through defuzzification process.
Necessary steps for the edge detection as follows:
Step-1: Import the input image
Step-2: Chosen image may be RGB so covert RGB image to grayscale image
Step-3: Convert the image into single or double precision data
Step-4: Obtain gradient of the image
Step-5: Defining Fuzzy inference rules for edge detection
Step-6: Evaluate the result and redefine fuzzy inference if required
Step-7: plot the result

This research work address one of the challenging problems in image enhancement. Under the image enhancement process edges of the enhanced image has not able to detect properly. So, this hybrid intelligent process included the idea of image enhancement and edge detection. This hybrid intelligent approach uses convolution neural network for image enhancement process and the resulting image also gives the corner or edges of the image with the help of the fuzzy inference system. This type of the hybrid intelligent approach is one of the kinds of the novel approach which was never discussed in the previous study.

4. PROPOSED MODEL

In Figure 6 Image enhancement process elaborated step by step. In the first step medical image with noise value passed to the Denoising Convolution Neural Network which gives the enhance denoised image. The DnCNN comprises various convolution layer and Rectified Linear Activation function. This DnCNN gives the more enhanced image as compare with the other previous approaches.

In Figure 7 Fuzzy Edge Detection model elaborated here which describes the procedure of the edge detection using fuzzy inference system. In the first step any medical image converted into the grayscale image after the conversion image gradient calculated, and now the gradient of the image converted into the edges.

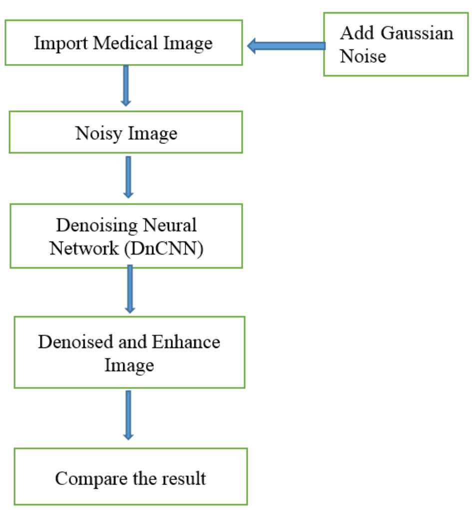

Figure 6. Proposed model of image enhancement

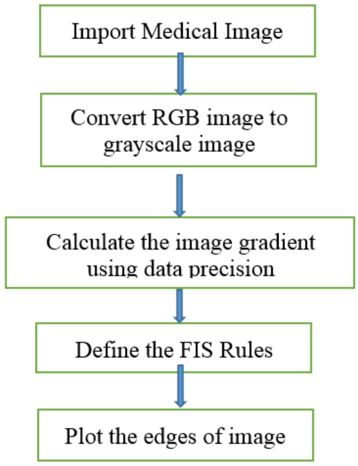

Figure 7. Fuzzy edge detection model

5. MATHEMATICS AND EQUATIONS

Images represented in matrix and several types of mathematics may be performed for the image enhancement and edge detection purpose [21].

Some terminologies and mathematics involved in image enhancement and edge detection as:

5.1 Mean square error

This is the error rate which should be calculated with respect to the image compression. This is the cumulative squared error with compressed and the original image.

$$MSE = \frac{\sum_{M,N} [I(m,n) - J(m,n)]^2}{(M \times N)} \tag{5}$$

Eq. (5) elaborates the formula of mean square error, which gives cumulative square error between the compressed and original image. $I(m, n)$ is the compressed image and $J(m, n)$ is the original image.

5.2 Peak signal to noise ratio

This is the very crucial parameter in image processing, it is the ratio of peak signal to noise power. Standard equation for PSNR as follow:

$$PSNR = 10 \log_{10} \frac{R^2}{MSE} \tag{6}$$

In Eq. (6) shows the peak signal to noise ratio, where R^2 is the signal power and MSE represents the mean square error.

5.3 Entropy

It is the statistical measure of the input image which represents randomness. It is useful to characterize the image.

$$sum(p.*\log 2(p)) \tag{7}$$

Eq. (7) shows the entropy of the image in which p indicates that the normalized histogram counts.

5.4 Structure similarity index

It is another quality assessment of the image, where all three values can be calculated luminance, contrast and structural. The SSIM is the multiplicative of the above three terms [22].

$$SSIM(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x,y)]^{\gamma} \quad (8)$$

Eq. (8) indicates that the Structure similarity index which gives multiplicative values of the luminance l, contrast c and s is the structural term and α, β, χ are the exponents.

All the formulas and functions available in MATLAB.

6. EXPERIMENTAL RESULT AND DISCUSSION

All experimental study carried out in MATLAB 2020. MATLAB is a very powerful tool for the image processing. Image processing toolboxes available to solve any kind of the complex problems. Experimental setup required different images. Here different medical images are used for the various experiments. Result also compare with other traditional approaches.

6.1 Simulation results of image enhancement

Original Image (Left) Noisy Image(Right)

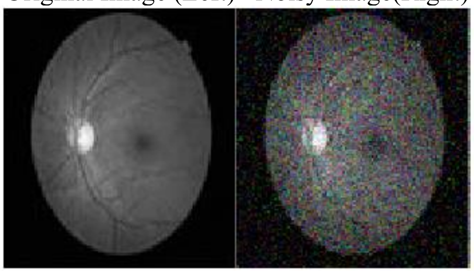

Figure 8. Original image with noisy image

Original Image (Left) Noisy Image(Right)

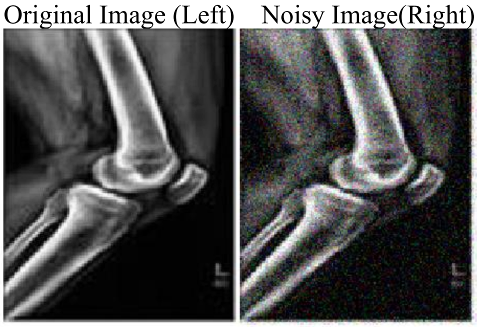

Figure 9. Original image with noisy image

Original Image (Left) Noisy Image (Right)

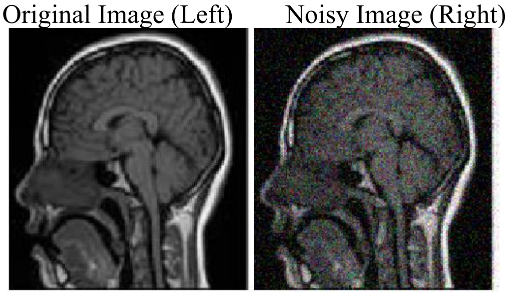

Figure 10. Original image with noisy image

Here Figures 8, 9 and 10 contains the original and noisy medical images (retina, bone, brain) respectively. Gaussian noise applied to the original images in MATLAB, so the corresponding noisy images may get generated. Now analysis the various enhancement techniques and proposed DnCNN.

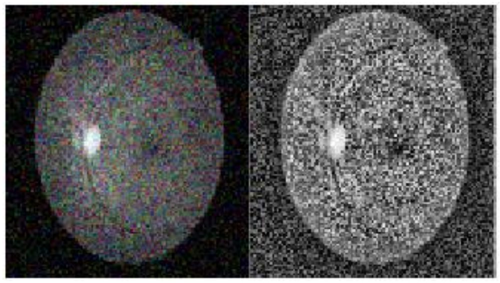

Figure 11. Noisy retina image and enhanced image using CLAHE

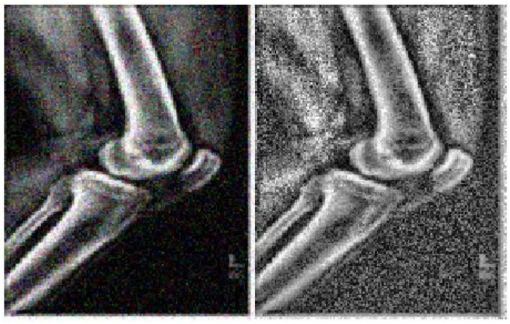

Figure 12. Noisy bone image and enhanced image using CLAHE

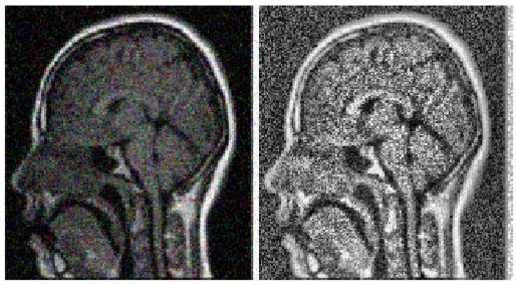

Figure 13. Noisy brain image and enhanced image using CLAHE

These are the enhanced medical images. Here retina, bone, brain images used for the enhancement purpose. As shown in the above Figure 11, Figure 12 and Figure 13 enhancement process using CLAHE (Special type of Histogram equalisation technique). CLAHE is the Contrast limited adaptive histogram technique.

Now the above noisy images inputted to the Denoising convolution network (Proposed Method). Input image is scatter into different layers and perform residual learning and finally denoised image get generated. DnCNN is a pretrained neural network model which was implemented in MATLAB 2020. It is a very powerful model to handle all types of noises. Here we used Gaussian noise for the simulation purpose. It smoothly removed the noise present in the image and also enhances the quality of the image. As shown in the above figures images have noisy and also not useful for the medical analysis purposes. This type of the problem efficiently resolved by the DnCNN, because it is a deep learning based model which can works all types of images, especially medical images.

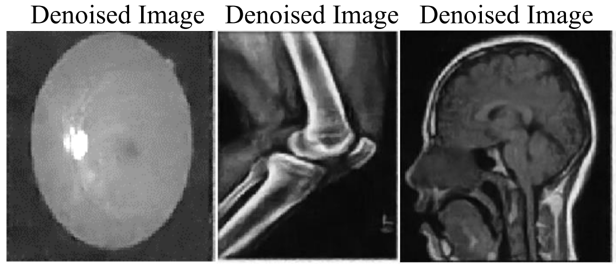

Figure 14. Denoised and enhanced image using proposed method (DnCNN)

Here the above figure three different medical images (Retina, Bone, Brain) denoised using the proposed DnCNN method. As shown in the Figure 14 the qualitative result compares with CLAHE in Figure 11, Figure 12 and Figure 13. DnCNN shown promising results.

6.2 Simulation result of edge detection

Edges are very crucial in image enhancement and also useful in image segmentation and object detection. Simulation performed on the different medical images (retina, brain and bone) and also implementation works perform on the MATLAB 2020 with the help of the image processing toolbox.

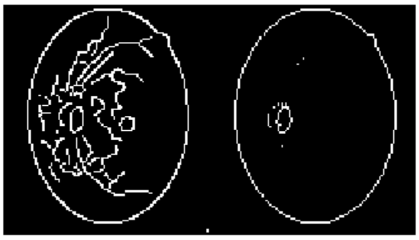

Figure 15. Edge detected of retina image using Canny and Prewitt filters

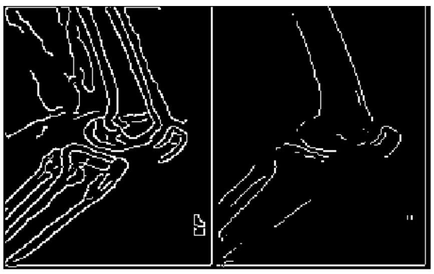

Figure 16. Edge detected of retina image using Canny and Prewitt filters

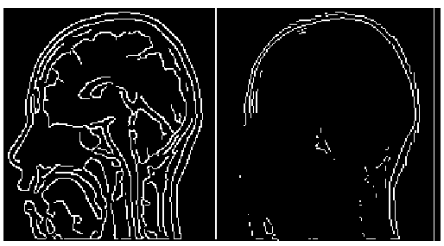

Figure 17. Edge detected of retina image using Canny and Prewitt filters

As shown in the above Figure 15, Figure 16 and Figure 17 above edges of the medical images are very clear and easily locatable, but still some kind of the improvement may exist.

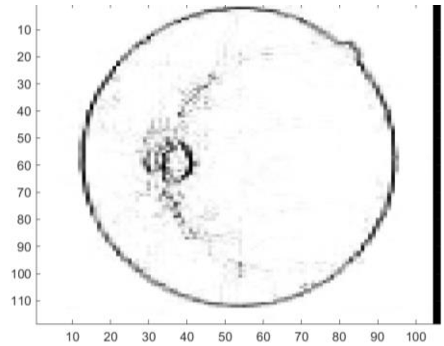

Figure 18. Edge detected of retina image using proposed fuzzy logic technique

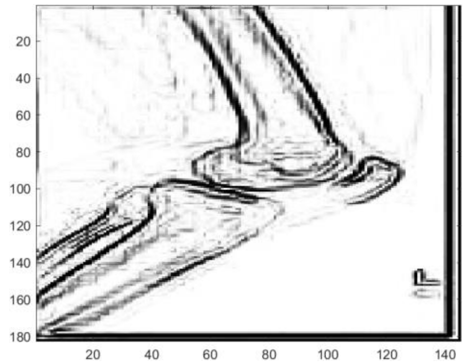

Figure 19. Edge detected of bone image using proposed fuzzy logic technique

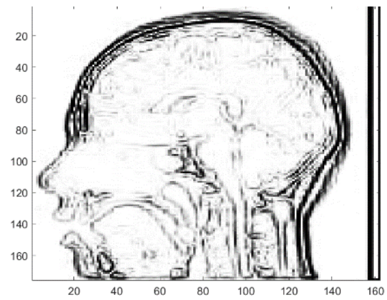

Figure 20. Edge detected of brain image using proposed fuzzy logic technique

As shown in the above Figure 18, Figure 19 and Figure 20 as per the qualitative measure fuzzy logic gives promising results as compare with Canny and Prewitt.

6.3 Performance metrics

Various types of performance parameter addressed here to compare the results of the different images over different approaches and proposed approaches.

PSNR (Peak Signal to Noise Ratio) gives the quantitative measure of the image. Higher values indicate the good image quality while low value indicates the lesser image quality. Simulation results shown the different values of the PSNR with corresponding image. Here results compare with the Contrast Limited Adaptive Histogram (CLAHE) and DnCNN Proposed approach.

Table 3. PSNR values of the different images

Image type	CLAHE	Proposed DnCNN approach
Retina	13.3274	25.9670
Bone	13.5927	26.4246
Brain	12.1928	26.3980
Average PSNR	13.0376333	26.2632

As shown in the above Table 3 Peak signal to noise ratio of different medical image using proposed DnCNN. Values of the PSNR using proposed hybrid approach have a much higher values as compare with the other approach.

Table 4. MSE Values of the different images

Image type	CLAHE	Proposed DnCNN approach
Retina	3062.1802	165.2894
Bone	2836.5454	152.0632
Brain	3930.9173	149.0954
Average PSNR	3276.54763	155.482667

As shown in the above Table 4 different values of the MSE calculated with different images using CLAHE and proposed DnCNN model. In our proposed DnCNN approach values of the mean square error is very low as compare the contrast limited adaptive histogram based approach, as proposed model gives very promising results.

Table 5. Structure Similarity Index (SSIM) values for the different images

Image type	CLAHE	Proposed DnCNN approach
Retina	0.48669	0.53115
Bone	0.62786	0.68266
Brain	0.55034	0.68141
Average SSIM	0.554963333	0.63174

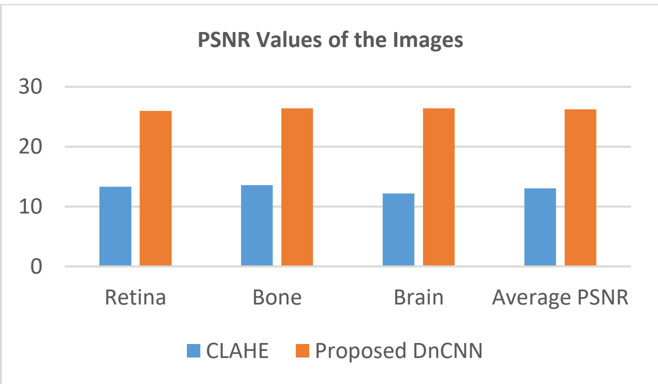

Figure 21. PSNR Values of sample images

As shown in the above Table 5 Structure Similarity Index values calculated over the different images with the help of the CLAHE and our proposed DnCNN model. Good values of SSIM achieve in the proposed DnCNN approach. Good SSIM value indicated luminance, structural and contrast of the image. The qualitative results like PSNR, MSE and SSIM index all the measure have a promising result over the retina, bone and brain medical images. Simulation works carried out with these images. Model may work other types of the medical images as well.

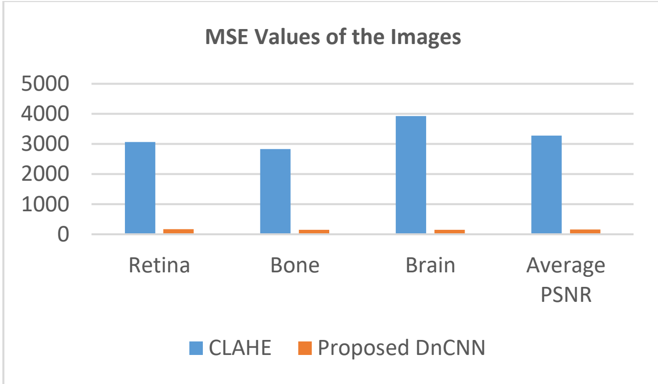

Figure 22. MSE values of sample images

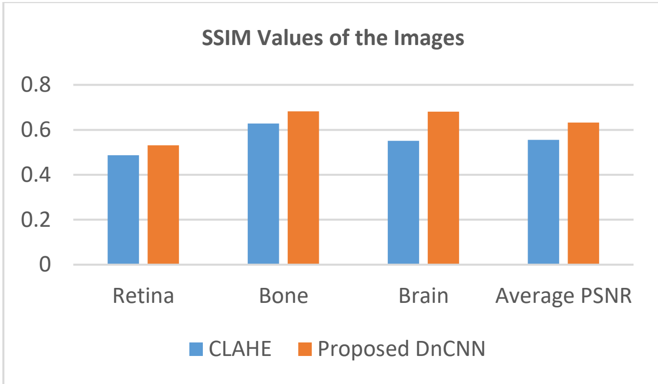

Figure 23. SSIM values of sample images

In the above Figure 21, Figure 22 and Figure 23 performance plots displays according the simulation data of image enhancements. As displays in the above figures it shows that proposed DnCNN works well for all the images used for the simulation purposes.

7. CONCLUSIONS

Here deep learning based denoised convolution neural network method used for the image enhancement and fuzzy logic used for the edge detection purpose. Both approaches are very useful for the medical imaging. The model for the image enhancement used here is DnCNN, this model is very useful for the all types of the images also covers all types of the noise and intensity. Under this model more image enhancement still possible and also improve the accuracy of the noisy images. In future more training over the different images still require to improve the accuracy of the model. In future Generative Adversarial Network (GAN) may be applied to resolve the limitations discussed here.

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