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TYPE 2 FUZZY BASED IMAGE ENHANCEMENT FOR BIO-MEDICAL APPLICATIONS

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Abstract- This paper presents a new Type-2 fuzzy based image enhancement by deploying contrast stretching, image suppression, and enhancement technique. The contrast stretching is executed using alpha blending technique. The image suppression is carried out using mamdani's fuzzy logic controller. The contrasted image and the suppressed image is multiplied and the final image obtained will endure image enhancement with the aid of gray level slicing technique. The quantitative and qualitative measures indicate that the results of the proposed method are better in image contrast enhancement by preserving the local information of the original image. The proposed method is tested on several medical images and gives better visual quality as compared to the existing standard methods.
Keywords –Image suppression, Image enhancement, Contrast stretching, Contrast enhancement, Fuzzy logic.

1. INTRODUCTION

The Image processing is widely applied in various fields of advancements such as medical applications, satellite imaging, automation, etc. Since there are numerous innovative technologies have been evolved in processing an image, still there is lack of clarity observed in the processed image. This lack of clarity in the processed image may cause negative effects in case of medical applicationsDigital Image Processing (DIP) is a process in which several operations or techniques are performed on a picture or an image to convert it into a digital form. This is executed in order to yield an enhanced image with better clarity and to excerpt beneficial data from an image [1]. In Image processing, the image is treated as a 2D signal, and previously defined signal processing methods are applied on the image [2]. The manipulation of the image is attained using various execution tools such as MATLAB/SIMULINK for specific requirements such as Image Enhancement, Image Recognition, and Image Compression, etc. The DIP created many applications in several fields such as Digital Media, Medical Image, Robotics, Navigation, Industrial Automation, Agriculture, Satellite Imagery, Military security, etc [3]. There are several types of images considered such as Gray scale images, Indexed images, RGB images, and Binary images. Image processing generally follows the steps such as importing the input image using digital photography, manipulating and analyzing the image, image enhancement and edge detection etc. Some of the images will be of very low resolution, like the satellite images, which leads to different errors [4]. These errors will be systematic in nature and they could be identified. Preprocessing method is used to correct the errors that occurred. Edge of any image is the rapid change of intensity in the image. In case of binary images, the changes are from 0 to 1 which represents the high frequency components in the image. The smoothing, enhancement, detection and localization are some of the steps generally carried out in edge detection. The image processing are applied in image visualization, image restoration and sharpening, image retrieval, measurement of pattern and image recognition, and change detection [5-9].

The different medical images captured should be of high accuracy and clarity for automatic detection of tumor. For capturing such high quality and high efficiency medical images, the Magnetic Resonance Imaging (MRI) technique is used [10]. MR imaging is frequently been used to attain the image of organs, joints and soft tissues as these section of images contain useful information for detection of tumor. The images obtained from MRI technique provide high resolutions where the detailed anatomical information to examine the brain tumor is obtained. These images can also be used in detecting the abnormalities or foreign bodies contained inside the brain [11]. Some of the methods generally well equipped for classification of MR images are fuzzy methods, neural networks, atlas methods, knowledge based techniques, shape methods and variation segmentation. In order to obtain enhanced results or images for medical applications where the false negative cases must be at a very low rate, the image processing is employed [12].

The double reading detection of the medical images may be a better technique for tumor detection. As the cost implied in double reading is very high, for medical applications the software assistance is of greater interest nowadays. The monitoring and diagnosing the diseases in the conventional methods solely rely on detection of presence of particular features based on the human observation [13]. This research focuses on medical image enhancement by deploying contrast stretching, fuzzy

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logic, and gray level slicing. Contrast stretching is a modest image enhancement technique that attempts to advance the contrast in an image by extending the choice of intensity values it contains to span a desired range of values. In fuzzy logic, by developing the set of fuzzy rules, image suppression is done. Then, the gray level slicing is incorporated for image enhancement to attain the enhanced image.

The rest of the paper is organized as follows. Related works are discussed in section II. Proposed research methodology and Result evaluation methods are explained in section III and IV. Result analysis are presented in section V. Concluding remarks are given in section VI.

2. RELATED WORKS

Several research works done in image enhancement by deploying different research techniques are discussed in literature. S.S. Bedi et al. [14] described that there are various approaches for modification of images which are employed by the image enhancement algorithms to achieve visually acceptable images and choice of such techniques or approaches depend on the particular functions to perform a specific task, observing characteristics, viewing conditions and image contents.

In [15], N. Dhanachandra et al. proposed a new technique for segmenting an image using K-clustering algorithm by deploying subtractive clusters to generate the initial centroid. In the proposed technique, first performed partial contrast stretching for improving the quality of the original image and then applied median filter for improving the segmented image. The final segmented result was compared with k-means clustering algorithm and concluded that proposed clustering algorithm obtained better segmentation. The tuning of the output images were also incorporated in the new technique by varying the hyper sphere cluster very carefully. Finally, the RMSE and PSNR were checked and observed that they had small and large value respectively, which were the conditions for good quality image segmentation. Some researchers proposed a histogram and fuzzy logic based enhancement technique [16] for low contrast color images. Two parameters such as K and M were used in the proposed technique, where K is the contrast intensification parameter and M is the average intensity value of the image calculated from the histogram. Based on the performance analysis and experimental results, the proposed technique is computationally faster than those existing advanced enhancement technique and the new technique is appropriate for enhancing low contrast color images.

A.K. Bhandari et al. [17] introduced an improved satellite images enhancement method based on the evolutionary algorithms. The paper provided a novel contrast enhancement method to improve visual quality of images for low resolution remote sensing CS algorithm. The experimental results such as PSNR and visual results in case of the new technique when tested on several satellite images show the superiority over conventional techniques. R. Kaur et al. [18] described that noise removal in image was one of the biggest challenging issue in the field of digital image processing. Several types of noise exist but the impulse noise elimination was one of the main issue. The high density of impulsive noise is still an open area for research. In this paper, various methods used for noise reduction were presented. The OMP based filter was found to be better for the preservation of structure in digital image and it performed well only at low level noise. This technique is not adaptable for preservation of edges or neighborhood of edges.

In [19], R. Rajendran et al. introduced a new enhancement method for enhancing low resolution medical images. This method used the techniques such as guided filtering, edge enhancement, contrast stretching, and image fusion to further improve the image quality. This method accurately enhanced the images and provided with desired outputs. When the simulations results are compared, the proposed method shows better performance than the other existing standard enhancement methods. In [20], S. Chib et al. studied a number of enhancement techniques and the performance evaluation of these techniques were carried out based on the parameters such as MSE, PSNR using LandSat images. The results revealed that the contrast stretching is an effective method in spatial domain for satellite image enhancement. It demonstrated that image enhancement techniques used for satellite images could also be applied in frequency domain. In [21], L.S.S. Singh et al. studied a technique of enhancement through edge sharpening and contrast enhancement of medical images using fuzzy techniques. The performance evaluation of these techniques were carried out based on the parameters such as EME and TEN to measure contrast and sharpness respectively.

3. PROPOSED RESEARCH METHODILOGY

The steps of image enhancement in the proposed enhancement technique is shown in fig. 2. In this proposed research method, first the input image undergoes contrast stretching. Here, by using α-blending technique the input image will be multiplied by the defined α value. Then, the image suppression takes place with the aid of fuzzy logic technique by incorporating fuzzy rules. The contrasted image and the suppressed image will be multiplied and the resultant final image will adapt gray level slicing such that the even number of sliced image will be eliminated. In black and white image, the maximum range of intensity level is from 0 to 255 level. In this proposed approach, the intensity levels adapted is from 100 to 160 level. The enhancement of the image could be shown by computing the performance evaluation parameters of the final image and comparing the results of the final image with the standard images. Fig. 1 shows the used sample medical images for this proposed technique.

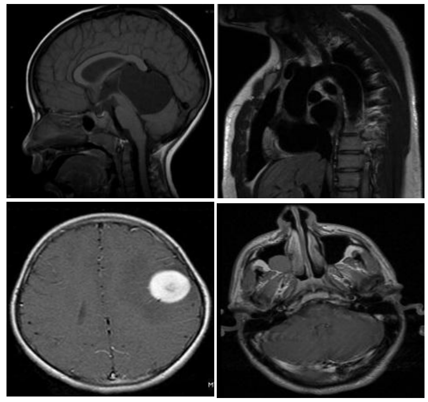


Figure 1. Used sample medical images

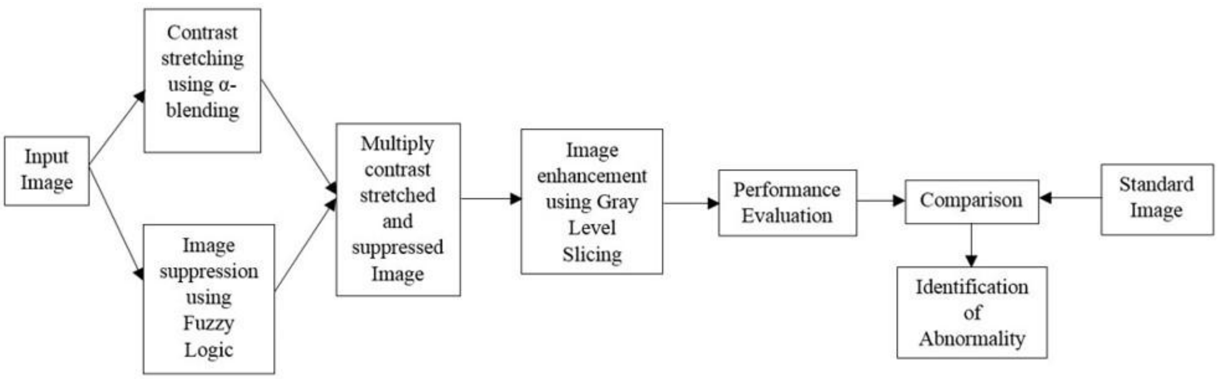


Fig. 2. Block diagram of proposed research method

3.1 Contrast Stretching –

In contrast stretching of the input image, the α-blending technique is used. The value of α used is 0.5. α- blending is a way of combining together of two images to form a new image. In computer graphics, the α-blending can be computed by multiplying each of the pixel from the initial source image along with the corresponding pixel in the next source image.

The general alpha blending computing equation is defined as,

$$Final\ pixel = \alpha * (Initial\ image's\ source\ pixel) + (1-\alpha) * (Next\ image's\ source\ pixel) \quad (1)$$

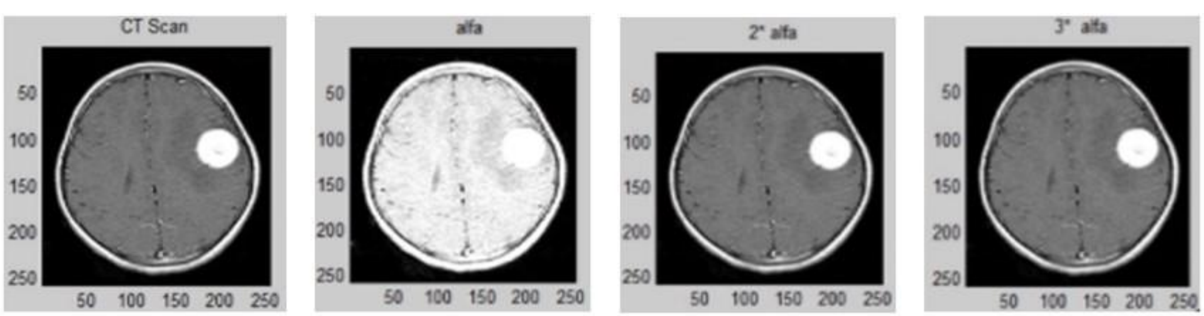
The blending factor or the percentage of the colors used from the initial source image in the blended image is known as alpha, 'α'. The alpha value used is in the range of 0 to 1. In this research, the alpha value is 0.5. The input image in which the contrast stretching is to be executed along with the corresponding alpha blended image is shown in fig. 3 where the intensity value is calculated by,

Intensity = nα

where,

n=1, 2, 3

α = 0



(a) Input image (b) α = 0.5 and n=1 (c) α = 0.5 and n=2 (d) α = 0.5 and n=3

Fig. 3. Input image and corresponding alpha blended images

3.2 Fuzzy logic image suppression -

Input image suppression is executed with the help of Mamdani's fuzzy logic controller. In this model of fuzzy inference technique, the fuzzy implication is modeled using Mamdani's minimum operator. The steps associated with mamdani's fuzzy logic controller are,

- Fuzzification
- Evaluation of rules
- Rule outputs Aggregation
- Defuzzification

Step 1: Fuzzification: - This step determines the degree of participation of the input that belong to each of the respective appropriate fuzzy set.

Step 2: Evaluation of rules: - In evaluation, the fuzzy rules antecedents apply on the fuzzy inputs. For multiple antecedent fuzzy rules, fuzzy operators such as AND or OR are used to obtain single number which represents the output. In the case of disjunction of the rule antecedent evaluation, the OR operation is used. Similarly, AND is used in the case of conjunction of the antecedent evaluation. The results obtained from the evaluation of antecedent will be applied on the membership function of the consequent. The cutting of membership functions at the level of antecedent truth is known as clipping which is the most commonly applied technique.

The clipped fuzzy set losses some of the information due to slicing of the top of membership function. Clipping is preferred as it is less complex and also easier to defuzzify. There is another method known as scaling which provides better approach for preserving the original shape of the fuzzy set. The multiplication of the membership degrees with the truth value of the rule antecedent can adjust the rule consequent membership function.

Step 3: Rule outputs Aggregation: - In this step, all clipped rule consequents membership functions are combined to a single fuzzy set.

Step 4: Defuzzification:- The defuzzification method used is centroid mode. In this method, it points out a Center Of Gravity (COG) of the aggregated fuzzy set on specific interval of time. A reasonable estimate could be obtained by computing it over a sample of points. Fuzzy logic controlled obtained suppressed image is shown in fig. 4.

For used images, the fuzzy rules are constructed. The set of fuzzy rules used are expressed as follows,

Rule 1

$$x(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} a(i,j) \oplus y(i,j).\,didj \tag{2}$$

$$x(i,j) = \left[\left[\left(a(i,j) + \bar{y}\,(i,j)\right) + \left(\bar{a}\,(i,j) - y(i,j)\right)\right]_{i=0}^{\infty}\right]_{j=0}^{\infty} \tag{3}$$

where,

x (i, j) - Correlated image

a (i, j) - Input Image

y (i, j) - Identity Matrix

As type 2 logic is considered, the correlation of matrices takes place and the image representation of the correlated image represents the first rule. As the enhancement of the image in the noise reduction plays a principal role in the image, here ex-or gate is represented which denotes the correlation property of the image.

Rule 2

$$y(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} a(i,j) - y(i,j).\,didj \tag{4}$$

$$y(i,j) = \left[\left[\left(a(i,j) + \bar{x}\,(i,j)\right) - \left(\bar{a}\,(i,j) + x(i,j)\right)\right]_{i=0}^{\infty}\right]_{j=0}^{\infty} \tag{5}$$

y (i , j) - Suppression level-1

$\bar{a}\,(i,j)$ - Inverted input image combined with correlated image extracted from Rule 1

$\bar{x}\,(i,j)$ - Inverted correlated image combined with input image

The 2nd rule is declared to enhance the noise suppression from the image in the form of augmentation of the correlated image and the input, so here the suppression is enhanced with the combination of the input image and the correlated image.

Rule 3

$$z(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} \bar{a}(i,j) \oplus \bar{y}(i,j).\,didj \tag{6}$$

$$z(i,j) = \left[\left[\left(\bar{a}(i,j) + y\,(i,j)\right) - \left(a(i,j) + \bar{y}(i,j)\right)\right]_{i=0}^{\infty}\right]_{j=0}^{\infty} \quad (7)$$

z (i , j) - Suppression level -2
$\bar{a}(i,j)$ - Inverted input image combined with correlated image extracted from Rule 1
$\bar{y}(i,j)$ - Inverted correlated image combined with input image
As rule 3 is designed to improve the data from the suppressed image, the maintenance of accuracy level will be achieved.

Outputs

$$ax(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} a(i,j) \oplus y(i,j).\,didj \quad (8)$$

$$bx(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} ax(i,j) \oplus y(i,j).\,didj \quad (9)$$

$$cx(i,j) = \int_{i=0}^{\infty}\int_{j=0}^{\infty} bx(i,j) \oplus bx(i,j).\,didj \quad (10)$$

where,
ax (i, j), bx (i, j) and cx (i, j) represent the outputs evolved from the suppressions made using fuzzy logic. cx (i, j) is the resultant of the fuzzy logic developed.

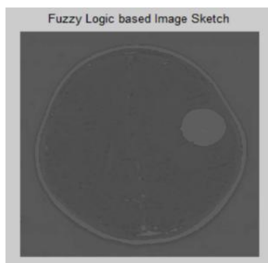


Figure 4. Suppressed image using fuzzy logic

The contrast stretched image and the suppressed image will be multiplied and the final image obtained is shown in fig. 5. The gray level slicing technique is applied to the resultant image to obtain the final enhanced image.

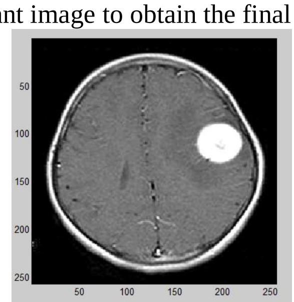


Figure 5. Image obtained after multiplying contrasted image and suppressed image

3.3 Image enhancement using gray level slicing -
Once the contrast stretched image and the suppressed image is multiplied and the final image is obtained, the image enhancement is done by deploying gray level slicing in which the even number of the sliced image will be eliminated. If r and s denote the pixel value before and after processing, then the expression for transformation is given as,

$$s = T(r) \quad (11)$$

where,
T is called as transformation that is used to map a pixel value r into a pixel value s.
In gray level slicing, the maximum intensity level of the black and white image is from 0 to 255. In this approach, the intensity level considered is from 100 to 160 level in order to yield better clarity in the enhanced image.

- In gray level slicing, the image will be sliced to equal number of pixels.
- If more than two pixels remains the same, they will be eliminated and the other part becomes clearer.

As the equal number of pixels will be removed from the frame, the uneven objects present in the image can be easily detected and the image becomes more enhanced and clear. This could be applied in medical imaging. The image obtained after deploying gray level slicing is shown in fig. 6.

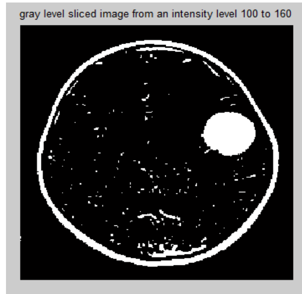


Figure 6: Final enhanced image after applying gray level slicing

4. RESULT EVALUATION METHODS

The proposed medical image enhancement method is tested on MRI and CT scanned medical images for evaluating its effectiveness. As there is no presently universally accepted image enhancement measuring mechanism, we used enhancement capability measuring techniques through quantitative and qualitative assessment. At present, no universally accepted computational metric is available that reliably specifies both the quantitative and qualitative measurement of an image enhancement method. So, to evaluate the qualitative and quantitative assessment, the experimental results of the proposed technique are compared with the results of the widely used standard method such as Histogram Equalization (HE).

4.1 Qualitative assessment -

The qualitative assessment is carried out by carefully inspecting the set of visual results of the proposed technique and comparing them with the relative results of the popular existing technique. In this paper, we referred HE as the standard technique.

4.2 Quantitative assessment -

In addition to qualitative measurement, we also employ objective metrics that are frequently used in the literature for assessing the enhancement algorithm results. In this paper, we employ three popular computational metrics such as root mean-square contrast (RMSC) [22, 23], contrast enhancement factor (CEF), and mean structural similarity metric (MSSIM) [24, 25] to quantify the degree of contrast enhancement and also to show the visual similarity between the original input image and the enhanced image.

Images yield from enhancement techniques should have the natural visual appearance with the input image. To evaluate the contrast effectiveness of the enhancement technique, RMSC is used. It is defined as.

$$RMSC = \sqrt{\frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}|I(i,j) - \bar{I}|^2} \tag{12}$$

where I represents the input image and $\bar{I}$ the average of I respectively. RMSC values indicate the contrast of the image. If the RMSC values are larger, then it usually indicate better image enhancement.

4.3 Contrast Enhancement Factor (CEF) -

To evaluate the effectiveness of the RMSC, CEF is used and is defined as

$$CEF = \frac{RMSC\,(I_r)}{RMSC\,(I_o)} \tag{13}$$

where, I_0 and I_r respectively represent the original and output images.

4.4 Mean Structural Similarity Metric (MSSIM) -

When undesirable artifacts are introduced in the image and noise is enhanced, the values of RMSC are increased. So, the larger value of RMSC is not sufficient to characterize the effectiveness of a contrast enhancement. The larger value of RMSC may also signal visual degradation and does not necessarily always indicate the visual enhancement. Hence, to reliably evaluate the quality of the contrast enhancement algorithms, the visual appearance of the enhanced images should therefore be taken into account and MSSIM can solve this measurably. It is defined as

$$SSIM(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu_x{}^2 + \mu_y{}^2 + C_1)(\sigma_x{}^2 + \sigma_y{}^2 + C_2)} \tag{14}$$

where,
$C_1 = (K_1L)^2,\ C_2 = (K_2L)^2$
L is the dynamic range of the pixel values
$K_1 = 0.01$ and $K_2 = 0.03$
Then

$$MSSIM = \frac{1}{M\times N}\sum_{x=1}^{M}\sum_{y=1}^{N} SSIM(x,y) \tag{15}$$

The value of MSSIM varies between 0 and 1. Hence, the higher value of MSSIM indicates a higher degree of retaining structural information. This index is therefore an effective measure of the distortions and noise induced in an image as a result of any transformation.

5. RESULT ANALYSIS

The result of the proposed technique (PT) is analyzed by comparing with the result of standard technique HE through qualitative and quantitative analysis testing on various different medical images and implemented by using MATLAB/SIMULINK tool.

5.1 Qualitative analysis -

For qualitative analysis we referred to the output results of our proposed technique and other standard technique (HE) for comparison. Fig. 7 shows the visual results of the proposed technique and standard HE for qualitative analysis of the PT. There are four different input images (image no. 1 to 4) with their respective results of HE and PT at different values of alpha. From the result images, we observed that HE gives over contrast result causing over exposed image while the proposed technique gives better result. In the following section, the corresponding quantitative analysis are discussed.

5.2 Quantitative analysis -

Table 1 and 2 show the RMSC, MSSIM, and CEF values for HE and PT tested on four images as shown in fig. 7. In each table, the last raw represents the mean measured value of the entire four tests. From Table 1 it is observed that HE scores higher value of RMSC for image 1 and 4 but less for image 2 and 3 causing respective CEF in Table 2, than that of PT while the mean value is lesser than that of PT. It means that HE gives better contrast result in two tests while PT gives in two tests. But, regarding mean of RMSC and CEF as in Table 1 and 2, PT gives better result than HE.
From Table 2 we observe that PT scores higher value of MSSIM for all the four tests showing that PT retain image structure much better than HE. From the above analysis, we can summarize that the Proposed Technique outperforms.

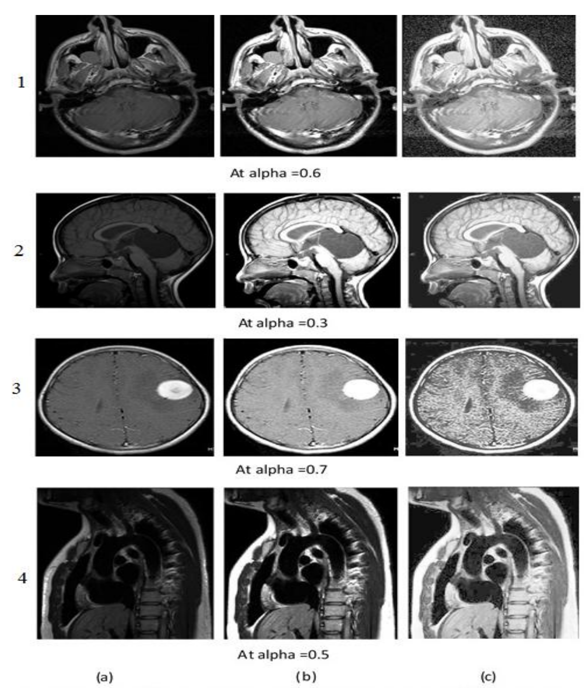


Figure 7. Visual output result comparisons (a) Input image, (b) PT and (c) HE

Table - 1			
RMSC Comparison			
Image No.	Input Image	Histogram Equalization	Proposed Technique
1	10.2068	10.8214	10.6385
2	9.4265	10.5880	10.6124
3	12.1850	10.6324	12.5061
4	8.0724	10.8194	9.9044
Mean	**9.9727**	**10.7153**	**10.9154**

Table - 2				
MSSIM and CEF Comparison				
Image No.	Histogram Equalization		Proposed Technique	
	MSSIM	CEF	MSSIM	CEF
1	0.3216	1.0602	0.6510	1.0423
2	0.4730	1.1232	0.4955	1.1258
3	0.4649	0.8726	0.9000	1.0263
4	0.2244	1.3403	0.6649	1.2269
Mean	**0.3709**	**0.8490**	**0.67785**	**1.1053**

6. CONCLUSION

This paper presents a new image contrast enhancement technique for medical images. It employs type 2 fuzzy technique. The algorithm combines alpha blending contrast stretching and fuzzy based image suppression technique. This method can solve the occurrence of artifacts, over enhancement and unnatural effects caused by other techniques of images enhancement. Subjective (visual) and objective (quantitative) evaluations are carried out for result image analysis testing on different medical images. Standard technique HE is used as reference technique to analyze the proposed technique. From the experimental results, it is observed that this proposed technique outperforms regarding contrast enhancement by retaining the overall image structure. The technique also preserves the perceptibility of inherent properties of the image.

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