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Comparative Analysis of Contrast Enhancement Techniques for Medical Images

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ABSTRACT

Contrast enhancement is the focus of this paper namely use of digital for medical imaging. Five types of images were analysed, namely hand, brain, head, ankle and knee. Three techniques have been used such as INT Operator, Fuzzy Type-1 and Fuzzy Type-2 on five different images. The obtained results have been compared based on four quality parameters, namely mean square error (MSE), normalisation coefficient (NC), root mean square error (RMSE) and peak signal to noise ratio (PSNR).Results showed INT Operator provides the best resultant image compared with other techniques.

Keywords: Contrast enhancement, INT operator, Fuzzy Type-1, Fuzzy Type-2

INTRODUCTION

A digital image is a numeric picture of a 2-dimensional image and compises rows and columns. Each block is named pixels. Digital image plays a vital role in medical imaging. Medical imaging technique generates visual structures of the internal organs. It shows the function of some organs or tissues. The important factor in any subjective evaluation of image quality is contrast enhancement. Contrast enhancement is mainly the difference in visual effects that makes an object separate from other objects and their background. It also improves the quality or clarity of images and increases the interpretability in images for human viewing.

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Contrast enhancement plays an important role in medical field or imaging. Contrast enhancement helps us to increase the brightness of an image. When some medical images havelow contrast, contrast enhancement is the best method to enhance the quality of image. Three enhancement techniques have been used in this paper. The INT is an intensification operator to decrease the fuzziness of an image. Fuzziness means dullness of the pixels. This technique contains some parameters to analyse the enhancement of digital images (Mahashwari & Asthana, 2013).

Fuzzy type-1 and fuzzy type-2 techniques show good contrast of an image. The result of type-1 fuzzy logic system is represented by single numeric values. It means only one membership function is performed using this method. Membership values are computed with the help of fuzzy hyperbolisation approach. This approach has three steps, namely fuzzification, membership modification and defuzzification (Hartati et al., 2009). Fuzzification converts gray level into membership values. The new gray levels are generated by the defuzzification step. It has four components: fuzzifier, rulebase, inference engine and defuzzifier and work based on membership function (Kaur et al., 2017; Wu, 2014; Pal et al., 1983; Pal et al., 1981).

Fuzzy type-2 approach is a special case of fuzzy type-1 set. This set overcomes the limitations of type-1 fuzzy set. Fuzzy hyperbolisation technique is also applied in this approach for computing new gray levels. There are four components: fuzzifier, rulebase, inference engine and output processor. Rulebase component contains IF-THEN rules of the domain. type-2 fuzzy sets represent uncertainty based on two membership functions, namely lower membership function and upper membership function (Castillo et al., 2012; Castillo et al., 2007; Ensafi et al., 2005).

Four quality parameters such as Mean Square Error (MSE), Normalisation Coefficient (NC), Root Mean Square Error (RMSE) and Peak Signal to Noise Ratio (PSNR) are used for comparing contrast enhancement techniques. The MSE and RMSE stands for mean square error and root mean square error respectively while PSNR and NC means peak signal to noise ratio and normalisation coefficient respectively.

The paper is structured as follows. Section II contains literature review while Section III briefly discusses contrast enhancement techniques i.e. INT Operator, Type-1 Fuzzy & Type-2 fuzzy. Section IV describes performance analysis and simulation results by considering different performance quality parameters. Section V concludes the paper and discusses the future scope of work.

BACKGROUND

Kundra et al. (2009) presented an image enhancement based on fuzzy logic. The main goal of this paper is to remove the noise and improve the contrast of an image using digital imaging. There two main steps: removal of impulse noise. This begins with gray scale image before applying the filter. The second step is to improve contrast of the image. According to this step, set shape of membership function and the value of fuzzifier beta according to the actual image is computed based on membership values. Further, membership values are changed using linguistic values to generate new gray-levels.

Hassanien et al. (2011) proposed the contrast for breast MRI images. Fuzzy type-2 technique is applied on different MRI breast images. This technique provides a higher accuracy compared with other techniques. The results of the fuzzy type-2 are compared with type-1 fuzzy technique. The type-2 Fuzzy approach provides better results compare to Fuzzy type-1 technique.

Tizhoush and Fochem (1995) has developed a hybrid technique for image contrast enhancement using fuzzy histogram hyperbolisation approach. This method provides better results for image enhancement. In this method they have taken X-ray image and satellite image for their result analysis. The main idea of this approach is to improve the contrast of the input images.

Preethi et al. (2013) has proposed the function modification using fuzzy logic. This paper represents the function modification using fuzzy logic and membership functions are modified to enhance finger prints. They have taken medical images for result analysis. This algorithm is also used to enhance the video images. Square and cube operator are applied for modifying new membership functions.

Lakshmi et al. (2013) have proposed an image contrast enhancement using the fuzzy technique. The existing algorithms manage uncertainties. The algorithm is used to calculate the parameters and is also applied on different types of images. The fuzzy technique is found to be a better technique compared with other techniques for contrast enhancement.

Mahashwari and Asthana (2013) proposed image processing theory based on a fuzzy technique using three steps, such as fuzzification, membership value and defuzzification. The proposed method was able to enhance the quality of image successfully.

Sesadri and Nagaraju (2015) proposed type 2 fuzzy technique for image enhancement. First, fisher criterion function was used to generate membership values of type-I fuzzy. Further, fuzzy rules are applied to generate enhanced image.

Khandewal and Kaur (2016) provides comparative study of different image enhancement technique. In this paper, six enhancement techniques were used to improve information in images. Erosion technique has produced best result with highest value PSNR and lower MSE value.

Kaur and Kaur (2016) compared enhancement techniques for medical images. In this paper, five enhancement techniques were used, namely average filter, bilateral ratinex, neighbourhood operation, imadjust and sigmoid function. Sigmoid function and neighbourhood operation produced the best result with low value of MSE & RMSE and high value of PSNR.

CONTRAST ENHANCEMENT TECHNIQUES

Three contrast enhancement techniques are used in this paper.

INT Operator

The INT is an intensification operator. This operator is used to decrease the fuzziness of an image. Fuzziness means dullness of the pixels. This technique contains some parameters to analyse enhancement of the image. Three steps are used to analysis this approach (Mahashwari & Asthana, 2013).

Step 1: Defining membership functions

$$\mu_{mn} = G(g_{mn}) = \left[1 + \frac{g_{max} - g_{mn}}{F_d}\right]^{-F_e}$$

Where

g_{mn} = Intensity value of pixel
g_{max} = maximum gray level
F_d = Denomination fuzzifier
F_e = Exponential fuzzifier

Denomination fuzzifier helps to increase the value in range [0, 1] and decrease fuzzified value.

Step 2: Membership modification

$$\mu'_{mn} = \begin{cases} 2 \cdot [\mu_{mn}]^2 0 \leq \mu_{mn} \leq 0.5 \\ 1 - 2 \cdot [1 - \mu_{mn}]^2 0.5 \leq \mu_{mn} \leq 1 \end{cases}$$

INT Operator modifies the membership values on a fuzzy setμ_{mn}. Cross over point is 0.5. The intensification operator steadily increases the value of μ_{mn} for increasing the values of cross over point from 0 to 1. This operator is applied on image again and again.

Step 3: Generate new gray levels

$$g'_{mn} = G^{-1}(\mu'_{mn}) = g_{max} - F_d\left((\mu'_{mn})^{\frac{-1}{F_e}} - 1\right)$$

The contrast depends on the increasing value of cross over point.

Fuzzy Type-1

The result of type-1 fuzzy logic system is represented by single numeric values. It means only one membership function is performed in this method. Membership values are computed with the help of fuzzy hyperbolisation approach. This approach has three steps, namely fuzzification, membership modification and defuzzification (Hartati et al., 2009). Fuzzification transforms gray level into membership values. The value of membership functions is changed after the fuzzification process. The new gray levels have generated in defuzzification step. Four components are used for processing type-1 fuzzy set, namely fuzzifier, rulebase, inference engine and defuzzifier. Fuzzifier transforms crisp value into fuzzy value. Rulebase component contains rules of the domain. Inference engine performs actions for fuzzy control. Defuzzifier transforms fuzzy value into crisp output value (Hassanien et al., 2011).

Step 1: Compute the type-1 fuzzy membership value using following equation:

$$\mu(g_{mn}) = \frac{g_{mn} - g_{min}}{g_{max} - g_{min}} \tag{1}$$

Where g_{mn} = Intensity value

g_{min} = Minimum gray level

g_{max} = Maximum gray level

Step 2: Compute the new gray levels

$$\tilde{g}_{mn} = \frac{L-1}{e^{-1}-1} \times \left[e^{-\mu(g_{mn})^{\beta}} - 1\right] \tag{2}$$

Where the parameter β is set to 0.8 and L is a number of gray levels.

Fuzzy Type-2

Fuzzy type-2 approach is the special case of type-1 fuzzy set. It overcomes the limitations of type-1 fuzzy set. Fuzzy hyperbolisation technique is also applied in this approach for computing new gray levels (Hartati et al., 2009). Fuzzification transforms gray level into membership values which are changed during the fuzzification process.

The new gray levels have been generated by the defuzzification step. Type-2 fuzzy sets represent uncertainty. Four components are used for processing, namely fuzzifier, rulebase, inference engine and output processor. Fuzzifier transforms crisp value into fuzzy value. Rulebase component contains IF-THEN rules of the domain. Inference engine performs actions for fuzzy control. Output processor contains type reducer and defuzzifier. Type-1 fuzzy set output and crisp number are generated from type reducer and defuzzifier respectively. Two membership functions are performed in this fuzzy set, such as upper membership function and lower membership function (Hassanien et al., 2011).

Step 1: Compute the upper and lower membership values by using the following equation:

$$\mu_{Lower}(x) = \mu(x)^2$$

and

$$\mu_{Upper}(x) = \mu(x)^{0.5}$$

Compute a window of size 21×21.

Determine type-2 fuzzy membership function using following equation

$$\mu_{T_{II}(g_{mn})} = (\mu_{Lower} \times \alpha) + \left(\mu_{Upper} \times (\alpha - 1)\right)$$

Where $\alpha = \frac{g_{mean}}{L}$

Step 2: Calculate the new gray levels using equation (2)

PERFORMANCE ANALYSIS AND SIMULATION RESULTS

Five types of experiment on given images were conducted and the various performance parameters were calculated to check the robustness of the algorithm.

The following quality parameters are considered:

1) **Mean Square Error:** It measures the average of the squares of the errors.

MSE = $\sum \frac{\sum(Y-\hat{Y})}{m \times n}$

Where Y= actual value, $\hat{Y}$ = predicted value, m= actual size and n= predicted size

2) **Root Mean Square Error:** It measures the difference between two similar images.

RMSE= √MSE

3) **Peak Signal to Noise Ratio:** It is a ratio between the maximum signal power and noise power.

PSNR = $10 \log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right)$

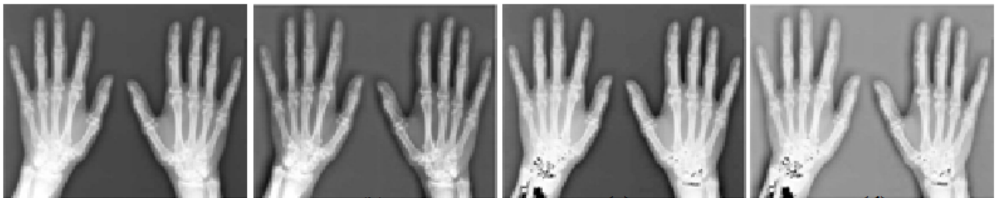
3) **Normalisation Coefficient:** It means range of values.

NC= $\frac{\sum_{s \in ref} M_s}{n_{ref}}$,

Where M_s= mean value for reference

Experiment 1

This is a hand image experiment. Three techniques were applied on first image shown in Figure 1. Various quality parameters have been calculated such as MSE, RMSE, PSNR and NC. These three techniques are compared based on four parameters shown in Table 1 and comparison of MSE and PSNR values are shown in Figure 2. It shows minimum value of MSE and maximum value of PSNR. It means the method have increased clarity of the image.



(a) (b) (c) (d)

Figure 1. (a) Original image; (b) INT Operator; (c) Fuzzy Type-1; and (d) Fuzzy Type-2

Table 1
Techniques comparison for hand image

Parameters	MSE	RMSE	PSNR	NC
F2	25.5444	0.4143	57.6458	0.00033
F1	4.3789	0.1681	89.5659	0.0012
INT	2.8159	0.1337	100	0.0019

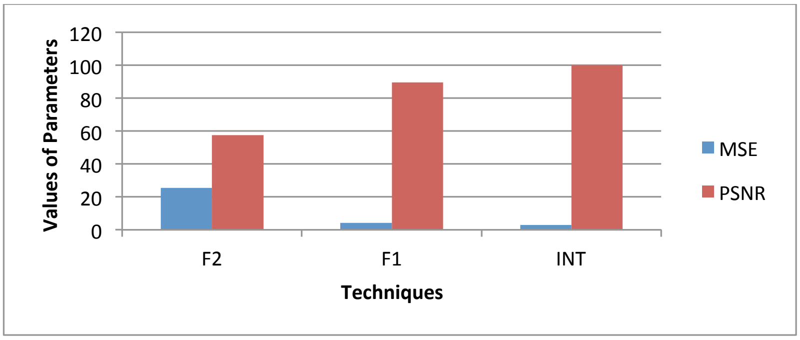
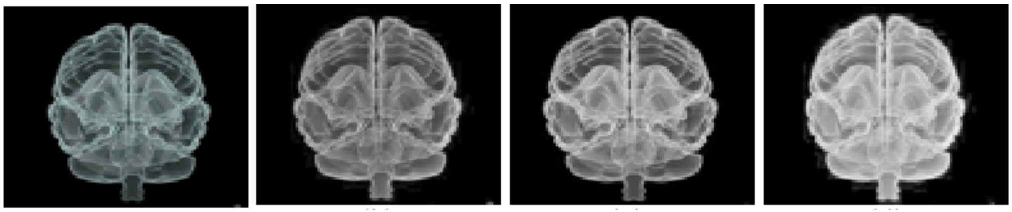


Figure 2. MSE and PSNR values comparison graph

Experiment 2

Three techniques were applied on brain image as shown in Figure 3. Various quality parameters have been calculated such as MSE, RMSE, PSNR and NC. These three techniques are compared and are shown in Table 2. Comparison of MSE and PSNR values are shown in Figure 4. Table 2 shows a minor value of MSE and RMSE which means maximum pixels are bright in the image. Figure 4 shows a greater value of PSNR which means they are brighter.



(a) (b) (c) (d)

Figure 3. (a) Original image; (b) INT Operator; (c) Fuzzy Type-1; and (d) Fuzzy Type-2

Table 2
Comparison of techniques for brain image

Parameters	MSE	RMSE	PSNR	NC
F2	10.6655	0.2419	57.0233	0.00040
F1	2.0279	0.1023	86.307	0.0014
INT	1.1226	0.0747	100	0.0028

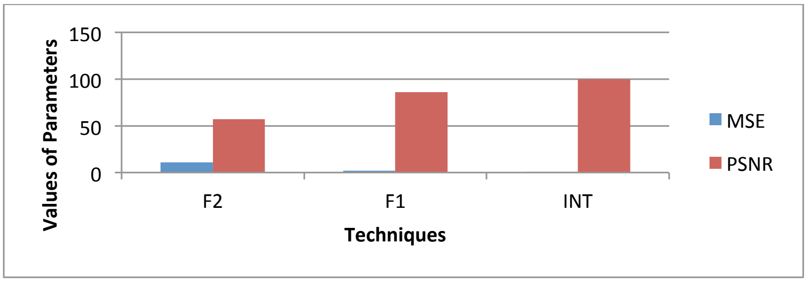
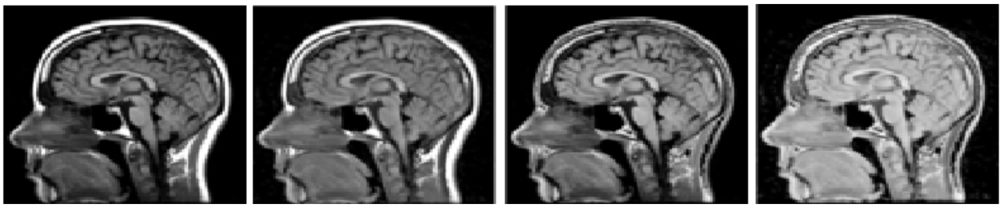


Figure 4. MSE and PSNR values comparison Graph

Experiment 3

The third experiment is a head image. Three techniques were applied and shown in Figure 5. Various quality parameters are used such as MSE, RMSE, PSNR and NC. These three techniques are compared based on four parameters shown in Table 3. The pixels are brighter based on parameters PSNR and NC. Figure 6 shows the comparison of PSNR and MSE values.



(a) (b) (c) (d)

Figure 5. (a) Original image; (b) INT Operator; (c) Fuzzy Type-1; and (d) Fuzzy Type-2

Table 3
Technique comparison for head image

Parameters	MSE	RMSE	PSNR	NC
F2	40.7719	0.5405	55.3084	0.0012
F1	14.7564	0.3225	71.3044	0
INT	3.81	0.1607	100	0.0017

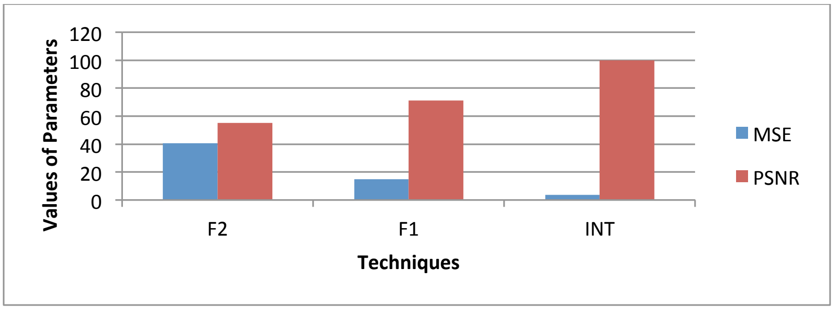
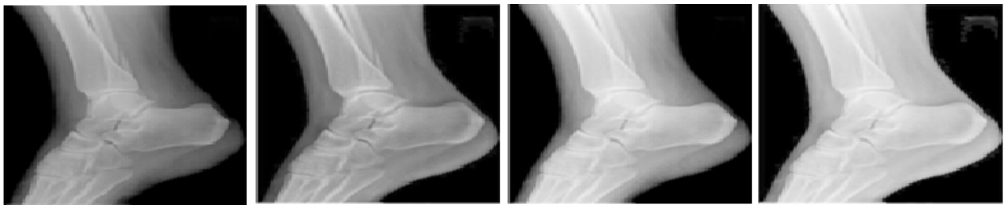


Figure 6. MSE and PSNR values comparison graph

Experiment 4

The fourth experiment is shown in Figure 7. Three techniques have been applied and compared with four quality parameters. Figure 8 shows the comparison of MSE and PSNR values. To check the robustness, various quality parameters have been calculated such as MSE, RMSE, PSNR and NC. Comparisons of these three techniques are based on four parameters shown in Table 4. Higher NC values mean good quality of image. The INT Operator always has higher NC values compared with the rest.



(a) (b) (c) (d)

Figure 7. (a) Original image; (b) INT Operator; (c) Fuzzy Type-1; and (d) Fuzzy Type-2

Table 4
Technique comparison for ankle image

Parameters	MSE	RMSE	PSNR	NC
F2	26.5421	0.4278	58.6169	0.0026
F1	10.7424	0.2704	73.4866	0.0043
INT	3.1294	0.1437	100	0.0049

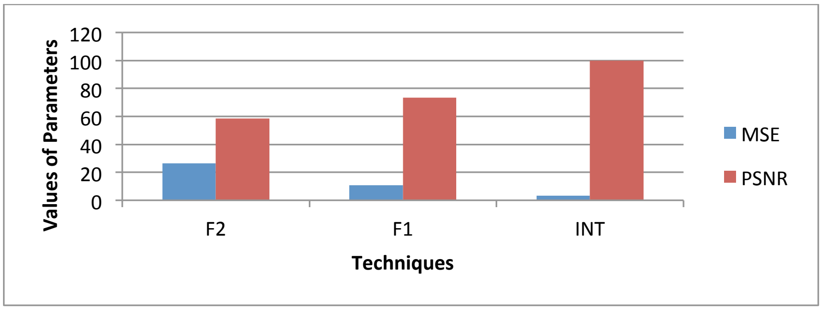


Figure 8. MSE and PSNR values comparison graph

Experiment 5

The fifth experiment is on knee image. Three techniques were used as shown in Figure 9. Various quality parameters are calculated such as MSE, RMSE, PSNR and NC. Table 5 shows a higher value of PSNR and NC for brightness.

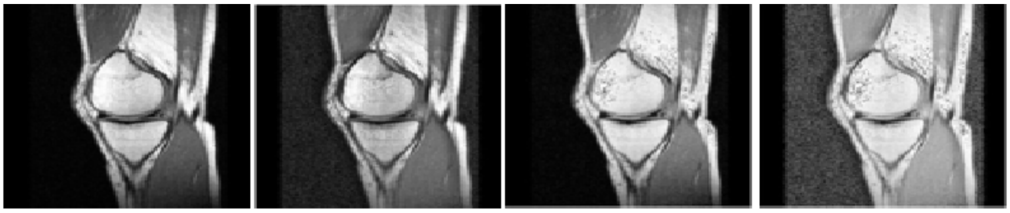


Figure 9. (a) Original image; (b) INT Operator; (c) Fuzzy Type-1; and (d) Fuzzy Type-2

Table 5
Techniques comparison for knee image

Parameters	MSE	RMSE	PSNR	NC
F2	26.0675	0.435	63.3894	0.00036
F1	5.0747	0.1882	95.4083	0.0012
INT	4.2038	0.1707	100	0.0018

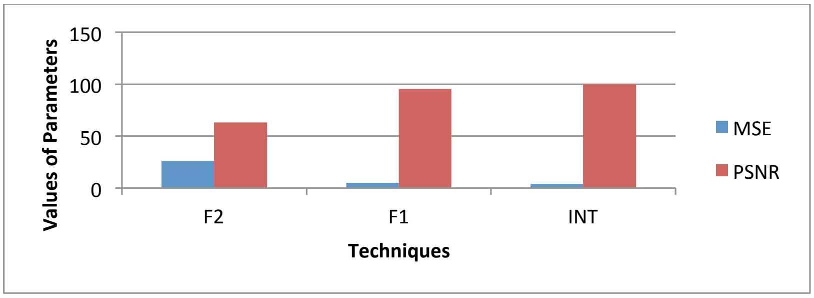


Figure 10. MSE and PSNR values comparison graph

COMPARATIVE STUDY AND RESULTS

Table 5 shows results of all 3 operators based on all the 5 images. We can clearly observe that INT Operator has the greatest value of NC in all images. First four parameters i.e. MSE1, RMSE1, PSNR1 and NC1 represent result for hand image. Next four parameters are expressing in table representation for brain image. MSE3, RMSE3, PSNR3, NC3 and MSE4, RMSE4, PSNR4 and NC4 are signifying outcome for head image and ankle image respectively. The rest of the parameters show result for knee image.

The result shows that the INT Operator is better than other techniques to increase the contrast of the images without edge detection. It means this technique improves the brightness of the image.

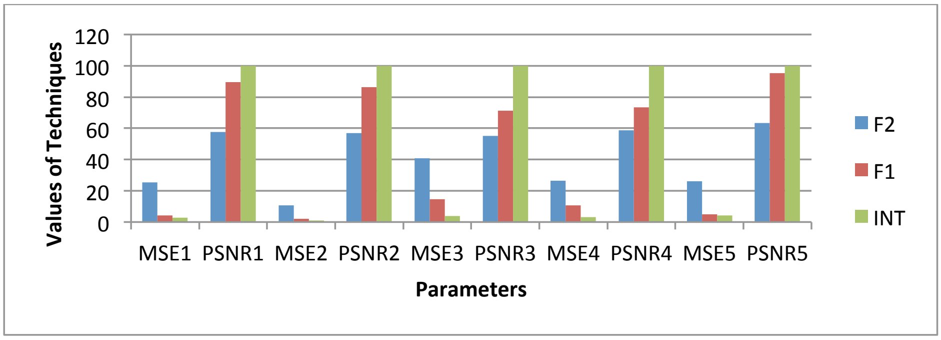


Figure 11. MSE and PSNR values comparison graph

Table 6
Technique comparison of five images

Image Name	Parameters	F2	F1	INT
Hand	MSE1	25.5444	4.3789	2.8159
	RMSE1	0.4143	0.1681	0.1337
	PSNR1	57.6458	89.5659	100
	NC1	0.00033	0.0012	0.0019
Brain	MSE2	10.6655	2.0279	1.1226
	RMSE2	0.2419	0.1023	0.0747
	PSNR2	57.0233	86.307	100
	NC2	0.00040	0.0014	0.0028
Head	MSE3	40.7719	4.7564	3.81
	RMSE3	0.5405	0.3225	0.1607
	PSNR3	55.3084	71.3044	100
	NC3	0.0012	0	0.0017
Ankle	MSE4	26.5421	10.7424	3.1294
	RMSE4	0.4278	0.2704	0.1437
	PSNR4	58.6169	73.4866	100
	NC4	0.0026	0.0043	0.0049
Knee	MSE5	26.0675	5.0747	4.2038
	RMSE5	0.435	0.1882	0.1707
	PSNR5	63.3894	95.4083	100
	NC5	0.00036	0.0012	0.0018

CONCLUSION

In this paper, various contrast enhancement techniques have been discussed for medical images. Three techniques, namely INT operator, Type-1 Fuzzy and Type-2 Fuzzy have been used on simple images (without edge detection). These techniques were compared based on four parameters: MSE, RMSE, PSNR and NC. Findings indicated INT Operator showed the best enhancement for simple medical images. It had a higher value of PSNR and NC.

Future research should focus on edge detection image.

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