INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Check for updates

OPEN ACCESS

**Received:** 31-03-2023

**Accepted:** 19-07-2023

**Published:** 28-08-2023

**Citation:** Kannan K, Perumal SA (2023) Enhancement of Proton Density Magnetic Resonance Images using Histogram Equalization and Unsharp Masking. Indian Journal of Science and Technology 16(32): 2534-2539. https://doi.org/10.17485/IJST/v16i32.747

* **Corresponding author**.

kannan_kcet@yahoo.co.in

**Funding:** None

**Competing Interests:** None



Published By Indian Society for Education and Environment (iSee)

**ISSN**
Print: 0974-6846
Electronic: 0974-5645

# Enhancement of Proton Density Magnetic Resonance Images using Histogram Equalization and Unsharp Masking

**K Kannan[1]*, S Arumuga Perumal[2]**

**1** Department of Mechatronics Engineering, KAMARAJ College of Engg & Tech, K. Vellkulam , 625701, India
**2** Department of Computer Science, S.T. Hindu College, Nagarcoil, 629001, India

## Abstract

**Objective:** The main objective of this study is to enhance the contrast and edge information present in the Proton density magnetic resonance medical images to increase the perception of information and provide better visualization format for effective diagnostics and treatment. **Method:** In the proposed algorithm, adaptive histogram equalization is applied to the input proton density magnetic resonance image to enhance the contrast followed by the unsharp mask filtering to improve the high frequency edge information of the image. Four proton density magnetic resonance images were downloaded from the dataset available in National Library of Medicine website, the experiment was carried out by writing the MATLAB code and executed by Intel Pentium Processor CPU4417U @ 2.3 GHz. **Findings:** Results reveal that the proposed method out performs adaptive histogram equalization (AHE) technique and Classical Unsharp Masking Filter (CUMF) both in terms of visual quality along with edge preservation and contrast enhancement. The quality of output image from the proposed method is enhanced by 1.34 times over AHE & 1.88 times over CUMF in terms of Spatial Frequency and 1.33 times over AHE & 2.18 times over CUMF in terms of Sharpness. **Novelty:** This study combines both histogram equalization and unsharp masking to enhance both contrast and edge information of proton density magnetic resonance medical images for effective diagnostics and treatment.

**Keywords:** Proton Density Magnetic Resonance Images; Medical Image Enhancement; Unsharp Mask Filter; Histogram Equalization; Spatial Frequency; Mean Gradient; Sharpness

## 1 Introduction

Proton Density Magnetic Resonance Images (PD-MRI) should consist of contrast and edge information about various parts of our body needed by Physician for diagnostic and treatment purpose. The sensors used in Magnetic Resonance imaging system may blur the image to some degree resulting low contrast which reduces the visual quality of the image. To increase the perceived quality of the PD-MRI images, edge information must be enhanced along with the contrast of the image. Global Histogram Equalization (GHE) is the most popular and widely used spatial domain image enhancement method to enhance the contrast of images taken by different imaging modalities. GHE method flattens the Probability Distribution Function (PDF) and improves contrast of an input image by stretching the dynamic range of gray levels from 0 to 255. Since it utilizes the cumulative density function (CDF) to enhance the gray levels of input image[(1)], the local contrast of an image is not improved. It varies mean brightness level of an input image and causes intensity saturation and over enhancement of image. The efficient technique to limit the level of enhancement in GHE method was proposed by Y.T. Kim and this method is called as like Brightness Preserving Bi Histogram Equalization (BBHE)[(2)]. To preserve the mean brightness while enhancing the contrast of input image, BBHE divides the input image histogram into two sub histograms based on the mean brightness, and both sub histograms are equalized independently. To preserve brightness along with average information content of the image, another technique called as, Dualistic Sub Image Histogram Equalization (DSIHE) was proposed by Wang et. al. which incorporates segmentation based on the median value[(3)]. To overcome the problem of over enhancement in DSIHE method, another technique called as Recursive Mean Separate Histogram Equalization (RMSHE) was proposed by S.D. Chen and A.R. Ramali[(4)]. RMSHE method uses mean based threshold for segmentation. Adaptive histogram equalization (AHE) is another method of histogram equalization for enhancing the contrast of the image that computes several histograms, each corresponds to a distinct window of an image. AHE over amplifies the artifacts in homogeneous regions of the image. A variant of AHE called Contrast Limited AHE (CLAHE) prevents this drawback by limiting the contrast amplification[(5)]. In literature, huge amount of histogram equalization based contrast enhancement techniques are available to solve the problem of mean brightness shifting and all the histogram equalization methods enhance the contrast of the image but fail to preserve the high frequency information. At the same time, the Classical Unsharp Mask Filter[(6)] (CUMF) and its different variants attract more attention from the researchers due to its simplicity in enhancing the high frequency edge information of various types of images. CUMF enhances the edge information but fails to enhance the contrast of the images. To overcome the limitation of both histogram equalization based techniques and CUMF, this study proposes a new approach to enhance the contrast and high frequency information like edges of low contrast PD-MRI images by combining CLAHE and CUMF. The proposed method provides satisfying results over GHE, BBHE, DSIHE, RMSHE, CLAHE and CUMF in terms of spatial frequency, mean gradient, entropy and sharpness. The following section presents the enhancement methodology. Section 3 discusses the performance of the proposed method. Finally, summary of this study with conclusion is presented.

## 2 Methodology

Adaptive histogram equalization and its variants are well-known contrast enhancement methods for all modalities of images ranging from satellite images to medical images. Similarly, Unsharp masking filter is well known for its simplicity and effectiveness in enhancing the sharpness of the images. This study combines CLAHE and CUMF to enhance the contrast and edge information of low contrast PD-MRI images simultaneously.

### 2.1 Contrast Limited Adaptive Histogram Equalization

Contrast-Limited Adaptive Histogram Equalization (CLAHE) is one of the most popular and acceptable variant of histogram equalization based contrast enhancement of digital images. This method is implemented by dividing the image into several non-overlapping regions of equal sizes called windows, resulting three regions namely Corner Region, Border Region and Inner Region. At first step, the histogram of each region is calculated. Then based on the clip limited defined by the user for contrast expansion, modified histogram is obtained in which the height of the histogram does not go beyond the clip limit. Finally, CDF of the modified contrast limited histograms are determined for gray scale mapping. In CLAHE method, pixels are mapped linearly by combining the results from the mapping of four nearest regions. Formulation of this approach for Inner Regions is straight forward. However, for regions in Corner Region and Border Region groups, this formulation requires some special consideration. The Figure 1 shows the comparison of contrast enhancement of an image along with the histogram by GHE and CLAHE.

### 2.2 Classical Unsharp Masking Filter

CUMF is widely used to sharpen the all type of images and its name originates from the fact that CUMF enhances high frequency information like edges and fine details. Figure 2 shows the structure of CUMF. It enhances the images through a process which subtracts the blurred version of an image from the original image to get the high frequency information. To generate the blurred version, normally Gaussian or box filter is used. The UMF can be computed using the following equation,

$$U(x,y) = I(x,y) + \gamma * [I(x,y) - G(x,y)]$$

where U (x,y) is the sharpened output image, I (x,y) is the original input image, G(x,y) is blurred version of Input image I (x,y) which is filtered by a low-pass Gaussian filter. $\gamma$is a scaling constant, whose larger values increase the amounts of the produced sharpness.

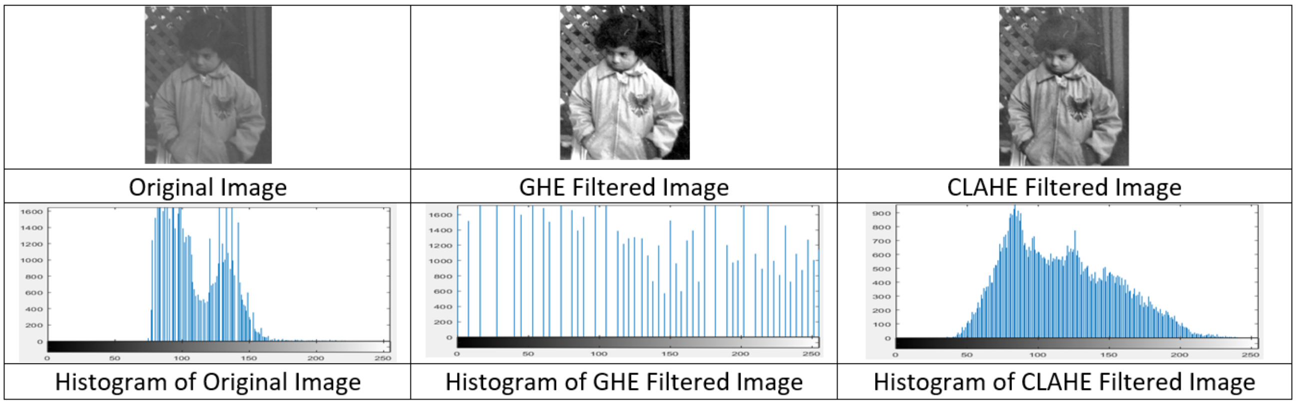


**Fig 1.** Comparison of Contrast Enhancement by GHE and CLAHE

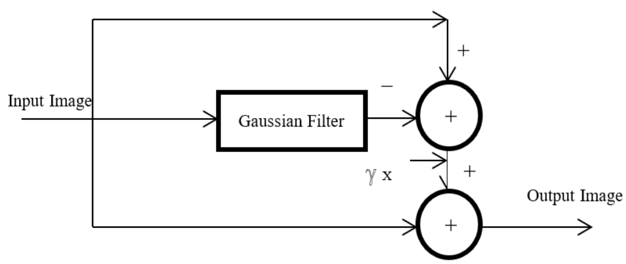


**Fig 2.** Classical Unsharp Masking Filter

## 2.3 Procedure

This study enhances the medical images and presents in a better visualization format to do medical analysis. This is achieved by enhancing the contrast and increasing visual quality of high frequency edge information of medical images. The proposed methodology to enhance the contrast and edge information is shown in Figure 3 . The proposed methodology receives the low contrast image as input and passes through the classical UMF. For implementing CUMF, this paper uses "imsharpen" in MATLAB. The scaling constant value $\gamma$is set to 0.8. The output from the classical UMF is the edge enhanced medical image and it is passed though contrast limited AHE. For AHE, the window size is set as 8X8 and the clip limit is set as 0.01 to avoid the over enhancement of contrast. The function called "adapthiseq" in MATLAB is used to implement CLAHE. The output from CLAHE is edge and contrast improved image.

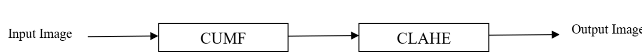


**Fig 3.** Proposed Methodology

## 3 Results and Discussion

Experimental evaluations and results are provided in this section to find out the strength of our proposed methodology in enhancing the medical images. The image enhancement based on Global Histogram Equalization (GHE), Brightness preserving Bi Histogram Equalization (BBHE), Dualistic Sub Image Histogram Equalization (DSIHE), Recursive Mean Separate Histogram Equalization (RMSHE), Adaptive Histogram Equalization (AHE), Classical UMF (CUMF) and the proposed method was implemented using MATLAB simulation package. Four proton density weighted magnetic resonance images (namely Thorax, Abdomen, Pelvis and Thigh) were downloaded from the dataset available in National Library of Medicine website, the experiment were carried out on these images by writing the MATLAB code and executed by Intel Pentium Processor CPU4417U @ 2.3 GHz. The main objective of this study is to enhance both contrast and edge information present in the Proton density magnetic resonance medical images. The enhanced image should be evaluated qualitatively using visual display and quantitatively using image quality metrics. The image quality metrics considered for quantitative analysis are Spatial Frequency (SF), Mean Gradient, Entropy and sharpness[7–10]. These values are tabulated in Table 1 and visual quality results of Medical Image enhancement are shown in Figure 4.

**Table 1.** Results of Medical Image Enhancement

| **Image** | | | | **Thorax Image** | | | | |
|---|---|---|---|---|---|---|---|---|
| Method | Original | HE | BBHE | DSIHE | RMSHE | AHE | CUMF | Proposed |
| SF | 15.3905 | 33.3761 | 37.2352 | 34.3015 | 35.8584 | 34.1954 | 22.5162 | **47.2976** |
| Gradient | 10.3543 | 25.4241 | 25.6615 | 25.5831 | 21.4141 | 24.6603 | 15.2805 | **34.857** |
| Entropy | 6.5811 | 5.561 | 6.3478 | 6.464 | 5.9229 | 7.3491 | 6.6932 | **7.3693** |
| Sharpness | 8.2756 | 18.5795 | 19.6583 | 19.1702 | 17.2797 | 19.2232 | 11.4709 | **25.548** |
| **Image** | | | | **Abdomen Image** | | | | |
| SF | 19.1055 | 44.106 | 49.3994 | 44.9352 | 52.1819 | 41.5794 | 28.0799 | **56.0352** |
| Gradient | 13.0478 | 29.0542 | 31.2372 | 29.537 | 31.9149 | 29.7481 | 19.3497 | **41.0128** |
| Entropy | 6.9227 | 5.8903 | 6.743 | 6.8124 | 6.4185 | 7.7364 | 7.0151 | **7.7621** |
| Sharpness | 10.446 | 23.1873 | 24.9047 | 23.6056 | 25.3095 | 23.5424 | 14.5273 | **30.4978** |
| **Image** | | | | **Pelvis Image** | | | | |
| SF | 16.807 | 33.4107 | 36.9879 | 35.0125 | 37.9431 | 32.7635 | 24.2375 | **44.4145** |
| Gradient | 9.727 | 20.3111 | 21.3824 | 21.3051 | 20.9011 | 21.1661 | 14.2861 | **29.6185** |
| Entropy | 6.7442 | 5.7222 | 6.5094 | 6.5448 | 6.1287 | 7.4108 | 6.8069 | **7.4511** |
| Sharpness | 7.8652 | 15.9122 | 16.8956 | 16.698 | 16.8492 | 16.7658 | 10.8217 | **22.0763** |
| **Image** | | | | **Thigh Image** | | | | |
| SF | 18.6035 | 33.1502 | 34.4288 | 36.0675 | 33.5548 | 30.6707 | 25.8226 | **40.5658** |
| Gradient | 9.7279 | 22.5844 | 21.5624 | 23.2595 | 16.1691 | 18.8346 | 13.7889 | **25.7084** |
| Entropy | 6.2071 | 5.1479 | 5.9469 | 6.0073 | 5.3873 | 6.788 | 6.268 | **6.8172** |
| Sharpness | 7.8932 | 16.2652 | 16.2741 | 17.3748 | 13.2776 | 14.7728 | 10.4691 | **19.0004** |

In Figure 4, the four input images are shown in row 1. The enhanced images using GHE, BBHE, DSIHE, RMSHE, CLAHE and CUMF method is shown from row 2 to row 7 respectively. From the results, it can be observed that visual quality of the resultant images are not up to the mark. Over brightness is resulted in GHE method. The resultant image of CLAHE method is visually looking good but lacks in edge information. The CUMF enhances the edge information in the output image but fails to enhance the contrast of the images. The output image of the proposed method is displayed in row 8 of Figure 4. In that image, both contrast and edge information is present and looks so good. The quantitative analysis of the proposed method in comparison with various enhancement methods is done with the help of image quality metrics Spatial Frequency, Mean Gradient, Entropy and sharpness. Spatial Frequency and Entropy provide the level of clarity whereas Mean Gradient and sharpness provide the edge information. From the table, it is inferred that proposed method enhances both contrast and edge information of PD-MRI image. GHE increases the overall contrast of the input image, but the local contrast of an image is not improved since it stretches the dynamic range of gray levels from 0 to 255. BBHE slightly controls the improvement in brightness and increases the local contrast by dividing the input image histogram into two sub histograms based on the mean brightness, and both sub histograms are equalized independently. The brightness along with average information content of the image is preserved by DSIHE by segmenting the input image histogram based on the median value. Contrast Limited AHE limits the contrast amplification and maintains balance between local and global contrast of the input image. All histogram equalization methods enhance the contrast of the image but fail to preserve the high frequency information. CUMF enhances the high frequency edge information of input image but the contrast of the input image is maintained. The proposed method takes the advantage from CLAHE and CUMF enhances both the contrast & high frequency edge information of input image which is clearly evident from the images shown in row8 of Figure 4.

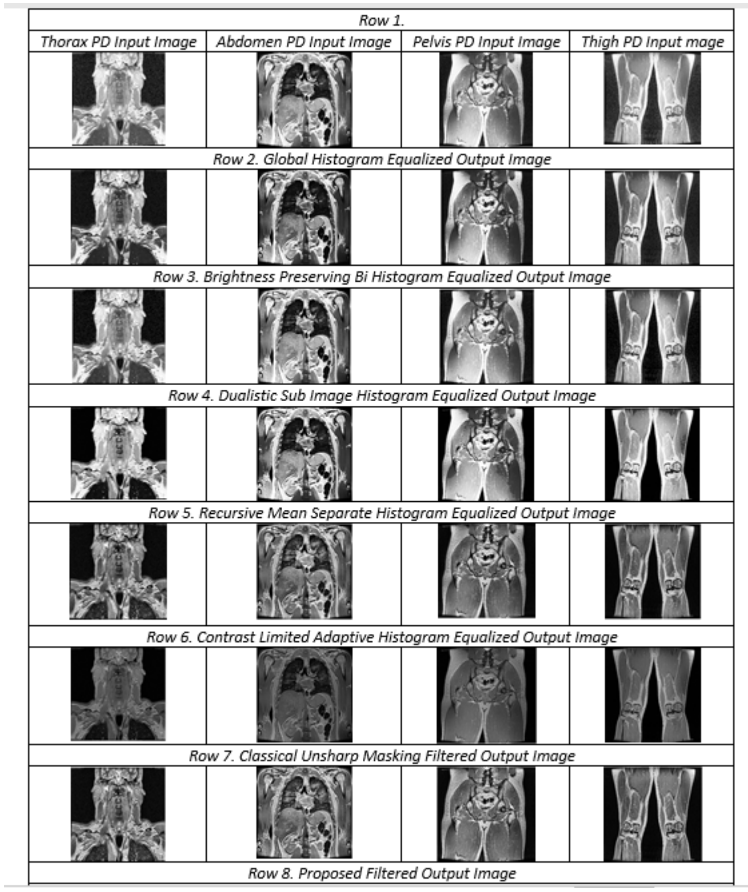


**Fig 4.** Results of Medical Image Enhancement

## 4 Conclusion

In this study, a novel method of medical image enhancement by combining adaptive histogram equalization and classical Unsharp masking filter is introduced. First, each input image is filtered using CUMF to enhance the edge information. Then, this edge enhanced image is filtered using CLHCE to enhance the contrast. As a result, the proposed methodology tremendously improves the edge information and enhances the contrast of PD-MRI images to do effective medical analysis. The proposed method is compared Histogram Equalization methods such as GHE, BBHE, DISHE, RMSHE, AHE and classical UMF. From the results, it is inferred that the histogram based methods improve the contrast but fail to enhance the edge details. The classical UMF enhances the high frequency edge information but fails to improve the contract of PD-MRI images. The proposed method enhances both contrast and edge details of PD-MRI Images. Furthermore, the accuracy of the obtained results is measured quantitatively using four well-known metrics like SF, Mean Gradient, Entropy and Sharpness. From the obtained results, it is well proven that the proposed method of enhancement by combining adaptive histogram equalization and classical Unsharp masking filter provided satisfying results and outperformed the CLAHE and CUMF in terms of qualitative and quantitative assessment. The quality of output image from the proposed method is enhanced by 1.34 times over AHE & 1.88 times over CUMF in terms of Spatial Frequency, 1.39 times over AHE & 2.13 times over CUMF in terms of Gradient and 1.33 times over AHE & 2.18 times over CUMF in terms of Sharpness. There is small increase in entropy from 7.321075 and 6.6958 to 7.349925 for the proposed method over AHE and CUMF. Even though experiments are demonstrated for PD-MRI images, proposed algorithm can also be applied on other medical imaging modalities as well.

## References


1) Gonzalez RC, Woods RE. Digital Image processing. Prentice Hall. 2018.
2) Tanaka H, Taguchi A. GHE Mechanism for Preserving Mean Brightness of the Original Image. *2021 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS)*. 2021. Available from: https://doi.org/10.1109/ISPACS51563.2021.9651115.
3) Thepade SD, Ople M, Mahindra V, Kulye V, Jamdar S. Low Light Image Contrast Enhancement using Blending of Histogram Equalization Based Methods DSIHE and MMBEBHE. In: 2022 2nd Asian Conference on Innovation in Technology (ASIANCON). IEEE. 2022;p. 1–5. Available from: https://doi.org/10.1109/ASIANCON55314.2022.9909318.
4) Ezhilraja K, Shanmugavadivu P. Contrast Enhancement of Lung CT Scan Images using Multi-Level Modified Dualistic Sub-Image Histogram Equalization. In: 2022 International Conference on Automation, Computing and Renewable Systems (ICACRS). IEEE. 2022;p. 1009–1014. Available from: https://doi.org/10.1109/ICACRS55517.2022.10029217.
5) Suharyanto, Hasibuan ZA, Andono PN, Pujiono D, Setiadi RIM. Contrast Limited Adaptive Histogram Equalization for Underwater Image Matching Optimization use SURF. *Journal of Physics: Conference Series*. 2021;1803(1):012008. Available from: https://doi.org/10.1088/1742-6596/1803/1/012008.
6) Shi Z, Chen Y, Gavves E, Mettes P, Snoek CGM. Unsharp Mask Guided Filtering. *IEEE Transactions on Image Processing*. 2021;30:7472–7485. Available from: https://doi.org/10.1109/TIP.2021.3106812.
7) Saraniya OSG. Image Fusion Through Deep Convolutional Neural Network. Academic Press. 2019. Available from: https://doi.org/10.1016/B978-0-12-816718-2.00010-5.
8) Wang HWCXDBCYDCWMMH. Image Quality Based on Gradient, Visual Saliency and Color information. *International Journal of Digital Multimedia Broadcasting*. 2022. Available from: https://doi.org/10.1155/2022/7540810.
9) Amelia CS. Entropy in Image Analysis. 2019. Available from: https://doi.org/10.3390/e21050502.
10) Liu Z, Hong H, Gan Z, Wang J, Chen Y. An Improved Method for Evaluating Image Sharpness Based on Edge Information. *Applied Sciences*. 2022;12(13):6712. Available from: https://doi.org/10.3390/app12136712.