American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-11, Issue-01, pp-126-137
www.ajer.org
Research Paper Open Access

Improved Enhancement Technique for Medical Image Processing

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ABSTRACT : *One of the most significant disadvantages of medical image enhancement algorithms is that they are frequently empirically developed and application specific. As a result, there is a need for the development of an appropriate algorithm capable of enhancing a variety of medical images for further processing by a computer-aided system(s). This paper presents an improved enhancement technique for medical image processing. The technique employs three different enhancement techniques. The first method is Un-sharp Masking (USM). The output of USM processing is fed into Logarithm Transformation (LT), Finally, the LT output is fed into the AHE. The performance of the proposed method was evaluate using AMBE, PSNR, Entropy and expect opinion score. The proposed method gave a robust result for AMBE, PSNR Entropy and outperformed conventional techniques, such as: HE, WT, CLAHE and FB with expert opinion score of 36 against 5, 21,24 and 3 for HE, WT. CLAHE and FB, respectively. The proposed enhancement process has demonstrated to function effectively with a medical image, including X-ray, MRI, and CT. The method bis a better competition to other conventional methods. It gives a brighter feature in low-energy image regions while having no effect on information in high-energy image regions.*

KEYWORDS *Entropy, Opinion score, CLAHE, Wavelet Transform, Histogram Equalization.*

Date of Submission: 10-01-2022 Date of acceptance: 25-01-2022

I. INTRODUCTION

Medical image processing is required for non-invasive examination and diagnosis of diseases, which can result in the early detection of life-threatening cases. Algorithms capable of improving medical images are frequently used to sharpen image features for display and further analysis. One of the most significant disadvantages of medical image enhancement algorithms is that they are frequently empirically developed and application specific. As a result, there is a need for the development of an appropriate algorithm capable of enhancing a variety of medical images for further processing by a computer-aided system(s).

The primary goal of medical imaging is to acquire images for both diagnostic and therapeutic purposes. Medical imaging modalities include magnetic resonance imaging (MRI), X-rays, and computed tomography, among others. These modalities frequently produce noisy, low contrast, and poorly illuminated images that require enhancement for better human and machine analysis results.

Enhanced medical images can also aid surgeons in more effective detection and diagnoses of ailments. Enhancement boosts the region of interest with a contrast enhancement approach appropriate for the intended purpose to rectify low contrast.

Medical image enhancement is quickly becoming an interdisciplinary research field, bringing together expertise from computer science, engineering, physics, biology, statistics, and biology. In addition, computer-aided diagnosis is quickly becoming an important part of clinical practice. Image enhancement techniques are required to achieve the following goals:

- To enhance the image contrast or suppress the noise to improve the quality of medical images for assessment by radiologists or other medical practitioners.
- To accentuate, smoothen, sharpen, or enhance the elements of a medical image for analysis and display.
- Increasing the dynamic range of specific attributes.
- To achieve better contrast in both dark and bright areas.
- To obtain information with a more natural frequency.

- To provide image quality with the fewest number of artifacts possible.
- To make it easier to implement and maintain brightness.

Medical imaging (MI) refers to the processes (generally non-invasive) that are used to provide visible images of a person's interior composition, mostly for research purposes. The findings of such investigations may lead to the development of appropriate treatments for disease detection and management. MI can generate a wide range of data for both normal and abnormal internal organs; however, these data must be improved before being sent into the CADx system for proper analysis. As a result, the relevance of medical image improvement cannot be overstated, as it may lead to improved CADx system performance.

Sonography, scopes, thermal magnetic, X-ray, gamma, and isotope imaging are a few of the MI technologies available for obtaining information about the position and status of the body's interior organs. When compared to external imaging techniques, these technologies have additional limitations. Medical images in the billions are captured each year for diagnostic purposes. Radiation modalities (ionizing and nonionizing) are used in over half of these images [1].

A digital image is a discrete function that denotes the quantity of physical appearance of a scene, such as color or illumination. Digital photographs have the advantage of reduced processing costs, easier transmission and storage, simple and inexpensive reproduction, flexible alterations, and immediate quality assessment. The downsides of digital images include loss of quality when resized, the need for a faster processor for modifications, and the need for more memory [2].

Image processing is the use of a computer to modify digital images for communication, storage, adaptability, and elasticity, among other things. Image processing dates back to the 1960s and has been used for a variety of clinical purposes. Image processing became cheaper and faster as computer systems evolved in the 1970s [3].

II. MEDICAL IMAGING SYSTEMS

These imaging systems typically use patient-generated signals to create images from nonionizing or ionizing sources.

A. X-ray Imaging Systems

Since the discovery of X-rays by Roentgen (a German scientist), X-rays have been utilized for MI. Electrons are generated in the cathode by a thermal emission technique and sped up by a potential difference of 50–150 KV in an X-ray tube. The X-rays are produced when electrons collide with the anode. Just 1% of this energy is transformed to X-rays, with the remainder converted to heat [6]. 2D plans of the internal structure are produced inside the X-ray machine. It utilizes a fluoroscopy to scan moving organs to produce images which could be displayed, transmitted or stored. Computed radiography (CT) images are produced via the use oof image receptors. Mammography images are produced via a low dose X-ray (low energy X-ray), it is used majorly to capture breast image.

B. Computed tomography (CT)

CT modality produce multiple dimension images as against the conventional radiography. Multiple slices of body tissues are produced in different directions by the CT scanner. The patient is scanned by rotating X-ray tube. A CT scanner generates multiple slices of body tissues in various directions. The patient is placed inside the CT scanner's aperture and scanned in all directions by a rotating X-ray tube [4].

III. LITERATURE REVIEW

Healthcare engineering, one of the world's important and rapidly growing industries, encompasses all aspects of illness prevention, diagnosis, treatment, and management, including the preservation and improvement of overall health and well-being through medical services [7]. Medical imaging technologies are increasingly being used not only for early disease diagnosis and treatment, but also for disease prevention, health check-ups, serious disease screening, patient monitoring, disease severity evaluation and therapies selection. The importance of medical imaging technologies in healthcare applications has grown steadily [8].

Medical image enhancement has become a normal task due to its ability to facilitate illness diagnosis and treatment, image-guided surgery, and other medical links more timely, accurate, and efficient. Cutting-edge image enhancement aids doctors in effectively interpreting medical images by creating outstanding tissue uniformity, optimal contrast, edge enhancement, artifact elimination, intelligent noise reduction, and other features [8, 9].

The field of medical image processing is vast and complicated. Medical images are necessary for diagnosing and treating patients. The doctor's ability to examine medical images will be hampered by poor image quality and contrast, resulting in processing issues. Furthermore, due to medical technologies and methods, physicians may have minimal control over the acquisition of medical images, resulting in nonhomogeneous brightness and contrast levels in medical images. As a result, improving picture quality and contrast in biomedical images is critical. X-rays, for example, may have little detail and contrast. Due to the absence of enough light injected into the cavity, frames obtained during minimally invasive surgery may have a significant darkened zone; foggy tissue often lack clarity in high contrast frames. Then, it is critical to identify images that require enhancement and to adaptively select the targeted dark regions for additional processing and image contrast enhancement. Researchers have developed a variety of image enhancement techniques, including the fuzzy method [10], histogram equalization method [11], histogram matching method [12] and equalized histogram equalization image enhancement method [13]. There are also other image enhancement techniques, such as nonlinear image enhancement [14] and wavelet transform [15, 16, 17].

The subject of medical imaging is becoming increasingly significant for diagnostic and therapy purposes in recent years. It is a complex field that includes professionals and experts in other fields and uses a variety of equipment for disease diagnosis, including Magnetic Resonance Imaging (MRI), Positron Emission Tomography, and Computed Tomography, among others. Computer Science, Electrical Engineering, and Electronics Engineering all have a part in medical imaging [18]. The presence of imaging information in disease diagnosis always has an impact on the diagnosis's outcome. The loss of information that occurs during the acquisition of an image, resulting in a reduction in contrast. The image's difficulty comes in the shape of gray levels, image contrast, and backdrop contrast, all of which make it difficult to segment or determine the borders of the blood vessels [19]. The primary goal of image enhancement is to smooth an image while taking non-impulsive noise into account. For noise reduction and segmentation, linear filters are used. The higher the contrast of the image, the easier it is to spot an incorrect disease diagnosis. This aids in the transformation of the image into a more acceptable format [20].

The goal of image enhancement techniques is to manipulate an existing image to improve its quality and visual appearance for a human viewer. Image enhancement is one of the most complicated, exciting, and significant areas of research in image processing because low contrast images are difficult to visualize. Many algorithms are developed to tackle complicated challenges in image visualization, data retrieval of the detected condition, and statistics using various types of images enhancing methods such as global [21], local [22] and hybrid [23]. Computed tomography, magnetic resonance imaging, mammography, and other imaging modalities are also available. MRI is a multi-planar imaging technology that allows for the capturing of images in the coronal and sagittal planes without bothering the patient in order to gain images of the body's interior structure.

Digital Image Processing (DIP) is a wide area of research that consists of numerous topics, one of which being Signal Processing [24]. Digital Image Processing (DIP) allows for image components manipulation as needed in a given application. DIP is utilized in a wide range of industries, including medical imaging, satellite photographs of planets and a variety of industrial applications. MRI, X-rays, Ultrasound, CT scan, and other medical images are used extensively in the medical industry to determine the specific problem in the patient's body. These images provide a detailed examination of a variety of disorders, including brain tumours, cancer, inflammation and so on. Thus, the physicians can better treat and identify the disease, the photos must be of high quality and contain all of the necessary information about the afflicted body part. Using image enhancement techniques to increase the visual quality of an image allows us to better localize pixels present in the input image, resulting in images with good contrast. MRI pictures have a low contrast. Various image enhancement techniques enable practitioners examine and treat the affected area by improving the brightness and contrast of the image. After enhancing the pictures and identifying the tumour location, the grade of the tumor must be determined.

Both diagnosis and therapy in digital health can be difficult to achieve with any degree of precision without medical imaging. An X-ray is a painless, rapid procedure that creates images of structures within the human body, especially bones. X-ray beams flow through the body, and depending on the density of the material they pass through, they are absorbed in varied amounts. Since its invention, the X-ray has been widely used in biomedical and medical sectors. X-rays have now become an important part of the medical diagnosing process. Although a medical X-ray image contains a lot of information, the details are fuzzy and the contrast is low, which has a negative impact on the doctor's decision. Thus, the important elements of this type of image improvement are improving image contrast and enhancing detail sharpness while suppressing noises [25]. The goal of medical image enhancement is to improve the image's perceptibility. Denoising, sharpening edges, enhancing brightness, improving contrast, and other image enhancement procedures provide benefits that allow doctors and clinicians to pay closer attention to minute details in the image. Contrast adjustment, histogram equalization, edge-preserving filters, wavelet-based algorithms, deblurring, and denoising are examples of enhancement techniques. Due to limitations in medical technology, medical images are frequently obtained with low-contrast, low-intensity, noisy, fuzzy, and other issues. These images are of poor quality and cannot be utilized for diagnosis. As a result, accurate image processing is required to provide higher-quality photos with more details for better analysis [26]. Numerous scholars have presented various approaches to deal with low-quality images in the previous few years.

Insufficient lighting, blurred edges and low contrast in medical photographs can be caused by differences in the density of various tissues in the human body, peristalsis of the tissue in the human body and sensor noise. The goal of medical image enhancement is to improve image contrast or characteristics in order to aid activities like clinical diagnosis and treatment decision-making. As a result, before studying a medical image, it is important to improve its quality [27].

Image enhancement technology is currently separated into two categories based on the processing space: spatial domain and transform domain. The first method involves directly processing the pixel space of the original image to improve brightness, which reduces image contrast and overwhelms details (e.g., Smoothing and sharpening filtering, Contrast Stretching, Compression of dynamic range, histogram equalization, gradient field equalization, and multiscale retinex [28]. When using spatial filtering to smooth an image, the edge information of the object in the image is weakened. Image contrast will be diminished when sharpening an image with spatial filtering. Although histogram processing cannot highlight image borders, it does have a stronger enhancing effect on medical photos with low dynamic range and inadequate lighting. The second method is to process in the transform domain to remove unwanted details and compensate for information loss during histogram equalization (e.g., Fourier transformation, Wavelet transformation, Curvelet transformation, non-sub-sampled contourlet (NSCT) transformation, none sub-sampled shearlet transformation (NSST) transformation, and so on). Wavelet transform (WT) offers good multiresolution analysis and time-frequency characteristics, which has been successfully employed in image processing. There are several image enhancing methods based on wavelet transform [29]. The non-linear transformation of the traditional wavelet transform is prone to causing visual deformation. A dyadic wavelet is a function that bridges the gap between continuous and discrete wavelets. When the signal is decomposed using the dyadic wavelet transform, it has strong directivity and there is no down sampling, therefore the sub band components acquired by decomposition of each layer are redundant. The dyadic wavelet transform's translation invariance ensures that the image's significant information is not greatly moved in the dyadic wavelet domain, successfully avoiding the visual deformation induced by the non-linear transformation. As a result, the dyadic wavelet transform is commonly utilized in image feature extraction, denoising, and augmentation [30].

A. Related Works

Various spatial domain enhancement techniques are discussed here. A technique that modifies the cumulative distribution function of medical image using the spline function was proposed by [31]. Histogram equalization technique stretches and flattens the histogram of the original image across the entire dynamic range (0-255) for medical image improvement [32]. Recursive mean-separate HE (RMSHE) recursively divides the image’s histogram into sub-histograms based on mean grayscale value, then equalize them individually to increase image’s contrast [32]. Recursive sub-image Histogram equalization technique was proposed by [46]. It enhances the histogram in a similar version to RMSHE, except that after setting the probability distribution function to 0.5, the histogram is recursively divided. [33] proposed adaptive HE with edge-based denoising technique which is in two stages: initial image de-noising with the wavelet-based de-noising technique and contrast enhancement with specific control parameters by adaptively stretching the histogram. Inverse sigmoid enhancement which improves X-ray images by using the inverse sigmoid function instead of the log function as a tone mapping in the retinex processing was proposed by [34].

Nonlinear transfer function with Un-sharp masking enhancement was proposed by [35]. It is a local brightness enhancement technique which separates the V-space image into smaller windows, calculates the non-linear transfer function of each window, and then enhances the pixels in each window before restoring the contrast of the brightness enhanced image. Un-sharp masking which improves contrast and overcomes the limitation of using a fixed scale value regardless of the input medical images, where scale values are chosen at random was proposed by [36]. Cuckoo search optimized image enhancement technique which uses Adaptive mutation and cross-over was proposed by [37]. It uses the same threshold value to determine the chance of establishing a nest and to adapt genetic operators.

Some of the transform techniques are covered in this section. 2D- QDFT Zonal rooting and alpha rooting enhancement method was proposed by [38]. In the technique, frequency spectrum is divided into zones using the zonal alpha rooting approach. It then uses alpha rooting with various alpha values for different zones. Modifies the reference grey lines to enhance or improve visual perception. Dark channel prior method [39] Enhances the contrast and highlights the details in an X-ray image that has been deteriorated by X-ray scattering, similar to the prior method of haze scattering by dark channel. [40] uses the luminance gain matrix and color space derived after performing gamma correction to the HSV (Hue, Saturation, and Value) channel to boost the contrast of RGB (Red, Green, and Blue) channels. Contrast In the case of the luminosity channel in L*a*b color space, limited adaptive histogram equalization boosts contrast.

IV. METHODOLOGY

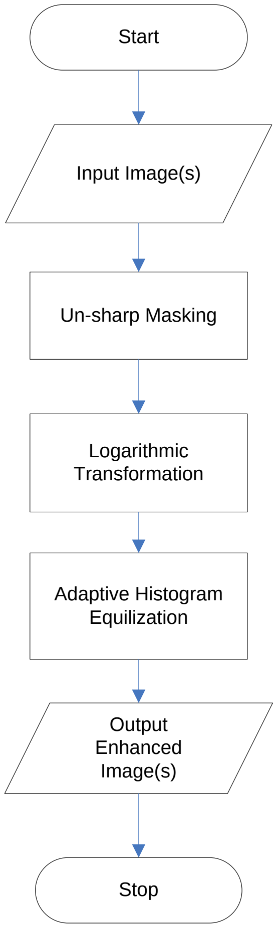

Fig.1. Flow Diagram of the Proposed Method

The flow diagram of the proposed medical image enhancement method is shown in Fig.1. As shown in the flow diagram, this study employs three different enhancement techniques. The first method is Un-sharp Masking (USM), which is used to sharpen the image by enhancing the edges and thus removing any blur that may be present in the input medical image. The output of USM processing is fed into Logarithm Transformation (LT), which aims to increase the brightness of dark pixels in the image for dynamic range improvement. Some of the hidden details are expected to be revealed by LT. Finally, the LT output is fed into the AHE technique, which is expected to improve contrast. The output of the AHE stage represents the final output of the proposed improved medical image enhancement scheme. The selection of these merged methods is influenced by their relative advantages over others, which include simplicity in terms of mathematical complexity, robustness, and speed. The algorithm of the proposed method is shown in Table 1.

TABLE 1. ALGORITHM OF THE PROPOSED METHOD

SN	STEPS
1	Input: medical image (s)
2	Output: Enhanced medical image (s)
3	If image (s) is color then
4	apply color space conversion (RGB to HSV)
5	read the value components of HSV
6	else:
7	apply log derived USM
8	apply LT
9	apply AHE
10	If image (s) is color then
11	compute new HSV value from H, S and V
12	Perform color space conversion (new HSV to RGB)

```
else:
output
Enhanced medical image
```

For image enhancement, the results of the proposed technique were compared to those of four other methods in the literatures. Histogram Equalization (HE), Contrast Limited Adaptive Histogram Equalization (CLAHE), a Wavelet Transform-based (WT) method by [41], and a Fuzzy-based method by [42] are the methods used.

V. RESULTS AND DISCUSSION

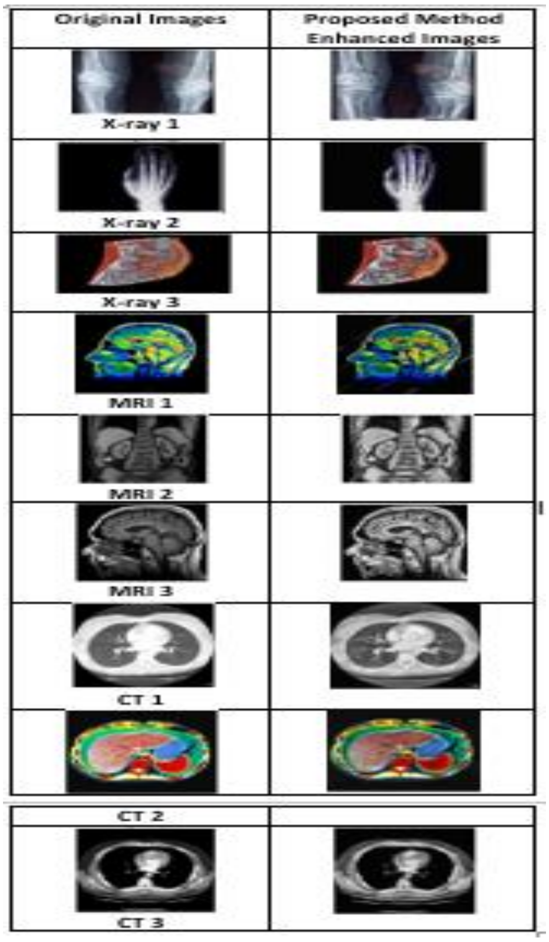

Fig.2. Original and Enhanced Images

Fig.2 shows images of the original test and the corresponding proposed method enhanced images. The results of the objective evaluation is shown in the histograms of Fig. 3 to Fig. 11. Fig. 3 shows the AMBE plots for MRI 1-3, Fig. 4 shows the PSNR plot for MRI 1-3, Fig. 5 shows the Entropy values for MRI 1-3. Considering the values of all the parameters, the proposed method performs better than the compared methods for the MRI test images.

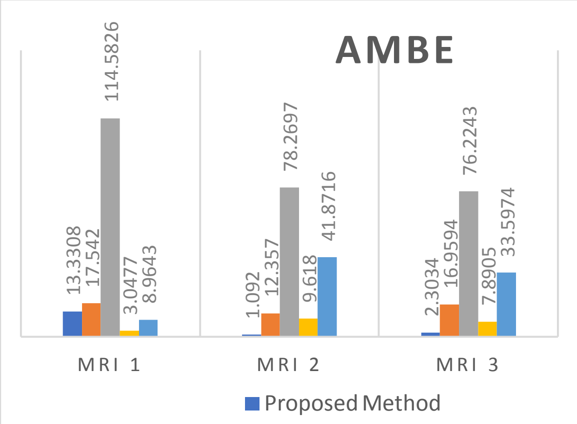

Fig.3. AMBE Histogram of the enhancement methods for MRI test images.

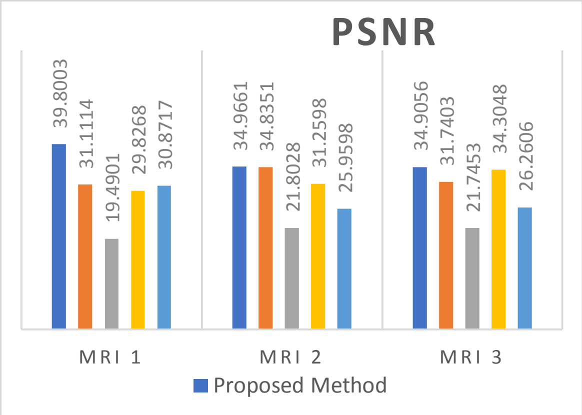

Fig.4. PSNR Histogram of the enhancement methods for MRI test images.

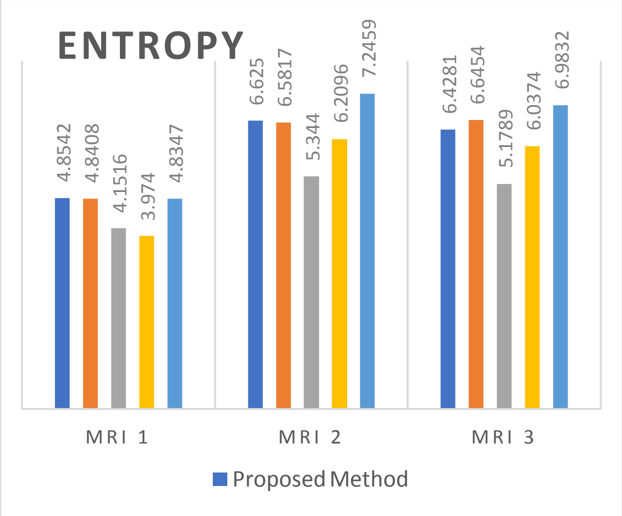

Fig.5. Entropy Histogram of the enhancement methods for MRI test images.

Fig. 6 shows the AMBE plots for X-ray 1-3, Fig. 7 shows the PSNR plot for X-ray 1-3, Fig. 8 shows the Entropy values for X-ray 1-3. Considering the values of all the parameters, the proposed method performs better than the compared methods for the X-ray test images.

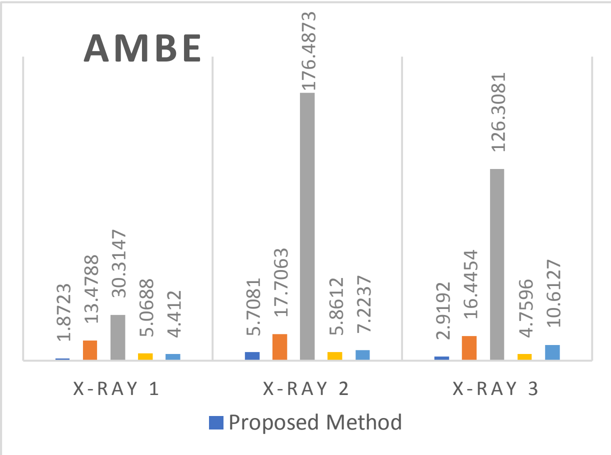

Fig.6. AMBE Histogram of the enhancement methods for X-ray test images.

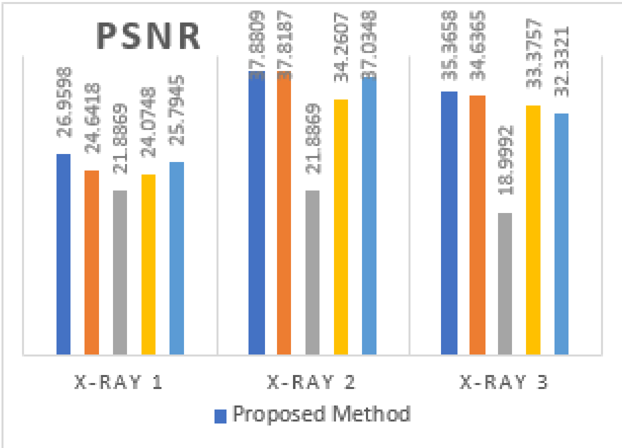

Fig.7. PSNR Histogram of the enhancement methods for X-ray test images.

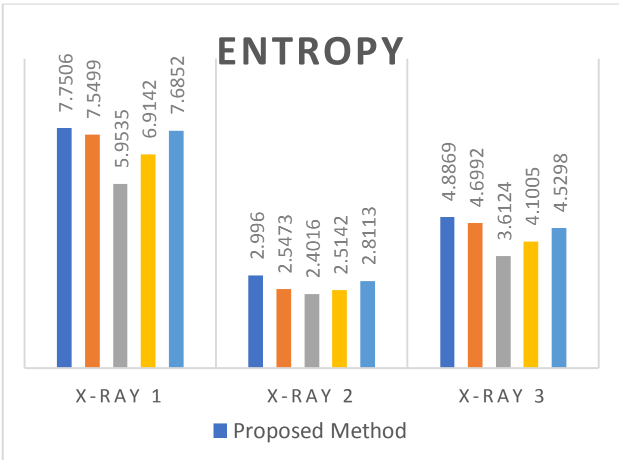

Fig.8. Entropy Histogram of the enhancement methods for X-ray test images.

Fig. 9 shows the AMBE plots for CT 1-3, Fig. 10 shows the PSNR plot for CT 1-3, Fig. 11 shows the Entropy values for CT 1-3. Considering the values of all the parameters, the proposed method performs better than the compared methods for the CT test images.

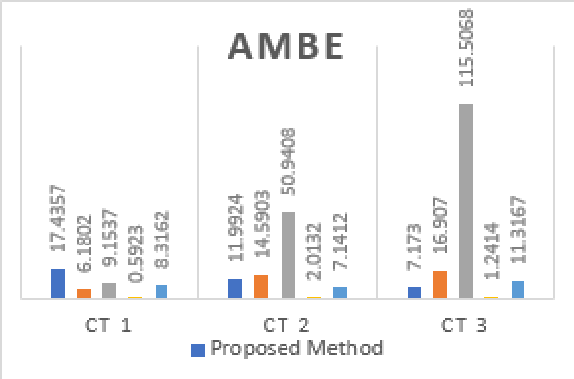

Fig.9. AMBE Histogram of the enhancement methods for CT test images.

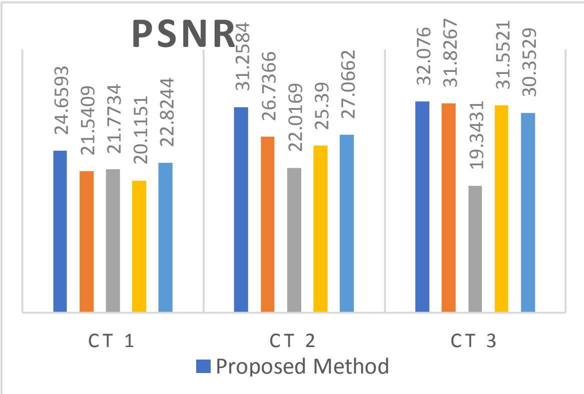

Fig.10. PSNR Histogram of the enhancement methods for CT test images.

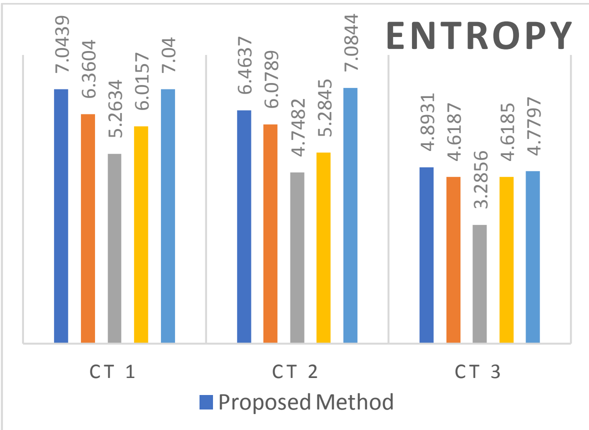

Fig.11. Entropy Histogram of the enhancement methods for CT test images.

The subjective parameter (visual inspection) performed by ten clinicians chosen at random yields an average percentage opinion score for the nine test images as shown in the multiple bar chart shown in Fig. 12. The overall opinion score is shown in the pie chart of Fig. 13. The opinion score results indicates that the proposed method performed better than the compared methods.

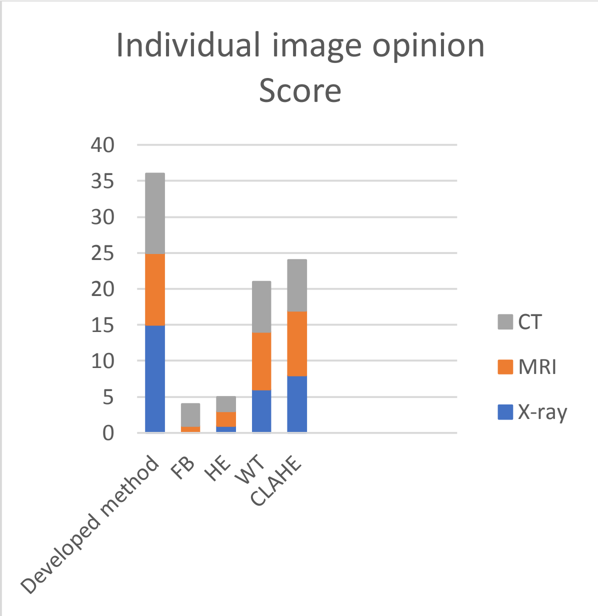

Fig.12. Opinion scores multiple bar chart of the enhancement methods for the test images.

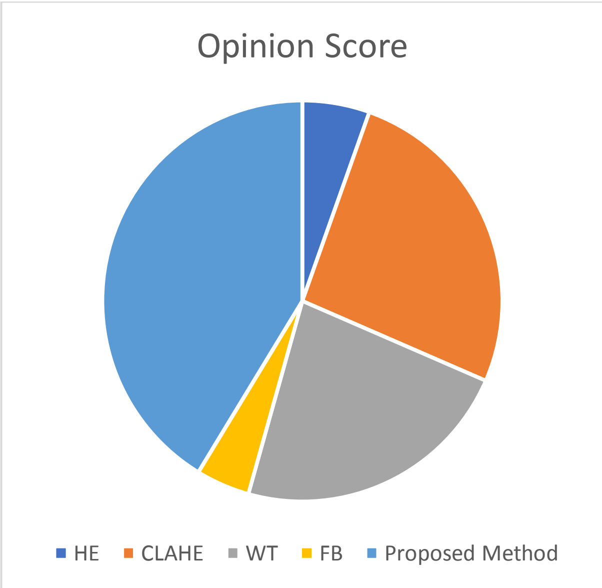

Fig.13. Opinion score piechart of the enhancement methods for MRI test images.

VI. Conclusion

Un-sharp masking is used to improve the input grey scale or V-image, which is then followed by a logarithmic transform and adaptive histogram equalization. If the input image is grey scale, the output image is the new gray scale image. If the input image is in color, the method creates a new HSV image by combining the new V- image with the prior H and S images, which stay unmodified. To create the enhanced color image, the new HSV is converted back to RGB.

The proposed enhancement process does not require the user to specify or alter settings, and it has been demonstrated to function effectively with a variety of medical images, including X-ray, MRI, and CT images. Other conventional methods, such as HE, CLAHE, a wavelet-based methodology, and a fuzzy-based approach, were outperformed by the new method. In comparison to the methods evaluated, it is certainly clear that the images obtained with the proposed method are of higher quality. The proposed enhancement, in particular, results in brighter features in low-energy image regions while having no effect on information in high-energy image regions.

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Olumayowa IDOWU, et. al. "Improved Enhancement Technique for Medical Image Processing."*American Journal of Engineering Research (AJER)*, vol. 11(01), 2022, pp. 126-137.