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MR Image Enhancement for Extra Axial Haemorhages Classification

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ABSTRACT: Intracranial hemorrhages (ICH) are classified on the basis of location and underlying vascular pathology. Depending on location , it is further classified into Intra Axial H. (IAH) and Extra Axial H.(EAH). IAH is divided into two types , Intra parenchymal and intra ventricular and EAH is divided into three types , Epidural H. , Subdural H. and Sub Arachnoid H. Distinguishing between EAH types is challenging due to similarities in clinical presentation and imaging. Magnetic Resonance Imaging (MRI) is one imaging modality that can be used in the early detection of EAH. The objective of this paper is to identify the best enhancement techniques in MR images for EAH classification [3]. 2 samples of MR images of each EAH type with final diagnosis were selected from Database Radiopedia.org. The MR images which were in Digital Imaging and Communications in Medicine (DICOM) format were later processed using 4 image enhancement techniques; Power Law Transformation, Histogram Equalization, Image sharpening and Median filter. All the 6 processed images were compared to obtain the best enhanced images on their Absolute Mean Brightness Error (AMBE) and Entropy values. Median Filter is the best image enhancement technique with average value of AMBE and entropy

KEYWORDS: Medical image processing, MRI brain image, Intracranial Haemorrhage, Extra Axial Haemorrage, Epidural, Subdural, Subarachnoid , Power Law Transformation, Median Filter, Image Sharpening, Histogram equalization.

I. INTRODUCTION

Traumatic Brain Injury (TBI) is a major public health issue. TBIs are a leading cause of morbidity, mortality, disability and socioeconomic losses in India and other developing countries. It is estimated that nearly 1.5 to 2 million persons are injured and 1 million succumb to death every year in India. Road traffic injuries are the leading causes (60%) of TBIs followed by falls (20%-25%) and violence(10%). Alcohol involvement is known to be present among 15%-20% of TBIs at the time of injury. The rehabilitation needs of brain injured persons are significantly high and increasing from year to year. India and other developing countries face the major challenges of prevention, pre-hospital care and rehabilitation in their rapidly changing environments to reduce the burden of TBIs [4].

Worldwide it is a major public health problem and is predicted to surpass many diseases as a major cause of death and disability by the year 2020.

Intracranial Haemorrhage (IH) is a common and serious consequence of TBI. IH has a number of causes, including: Head trauma, such as that caused by a fall, car accident, sports accident, etc. Hypertensive (high blood pressure) damage to blood vessel walls that causes the blood vessel to leak or break. Intracranial bleeding occurs when a blood vessel within the skull is ruptured or leaks. It can result from physical trauma (as occurs in head injury) or non traumatic causes (as occurs in hemorrhagic stroke) such as a ruptured aneurysm. Anticoagulant therapy, as well as disorders with blood clotting can heighten the risk that an intracranial haemorrhage will occur [4].

Types of intracranial haemorrhage are roughly grouped into intra-axial and extra-axial. The haemorrhage is considered a focal brain injury; that is, it occurs in a localized spot rather than causing diffuse damage over a wider

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area. Intra-axial haemorrhage is bleeding within the brain itself, or cerebral haemorrhage [2]. This category includes intra parenchymal hemorrhage, or bleeding within the brain tissue, and intra ventricular hemorrhage, bleeding within the brain's ventricles (particularly of premature infants).

Extra-axial haemorrhage (EAH), bleeding that occurs within the skull but outside of the brain tissue, falls into three subtypes: Epidural haemorrhage (EH or EDH) (extra dural haemorrhage) which occur between the dura mater (the outermost meninx) and the skull, is caused by trauma. This is a very dangerous type of injury because the bleed is from a high-pressure system and deadly increases in intracranial pressure can result rapidly [3]. Subdural haemorrhage (SHD) results from tearing of the bridging veins in the subdural space between the dura and arachnoidmater.

Subarachnoid haemorrhage (SAH), which occur between the arachnoid and pia meningeal layers, like intraparenchymal haemorrhage, can result either from trauma or from ruptures of aneurysms or arteriovenous malformations. The classic presentation of subarachnoid hemorrhage is the sudden onset of a severe headache (a thunderclap headache). This can be a very dangerous entity, and requires emergent neurosurgical evaluation, and sometimes urgent intervention[6].

A. IMAGING TECHNIQUES USED FOR DIAGNOSIS OF EAH

EDH, SDH and SAH have similar clinical presentation but are distinguishable based on imaging and histopathology. Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are examples of neurological imaging techniques that play an important role in the early detection of EAHs. In India, CT remains the EAH imaging modality in detecting acute bleeds due to its sensitivity, availability and cost whereas MRI with sequence of Gradient Recalled Echo (GRE) and Susceptibility Weighted Image (SWI) facilitate the clinician to identify the presence of chronic blood products in the brain.

B. MEDICAL IMAGE PROCESSING

Biomedical image processing has experienced dramatic expansion, and has been an interdisciplinary research field attracting expertise from applied mathematics, computer sciences, engineering, statistics, physics, biology and medicine. Computer-aided diagnostic processing has already become an important part of clinical routine. Accompanied by a rush of new development of high technology and use of various imaging modalities, more challenges arise; for example, how to process and analyze a significant volume of images so that high quality information can be produced for disease diagnoses and treatment. The discovery of seminal physical phenomena such as X-rays, Ultrasound, radioactivity and magnetic resonance and the development of imaging instruments that harness then have provided some of the most effective diagnostic tools in medicine[8].

During the past few decades, with the increasing availability of relatively inexpensive computational resources, computed tomography (CT), magnetic resonance imaging (MRI), doppler ultrasound, and various imaging techniques based on nuclear emission (PET (positron emission tomography), SPECT (single photon emission computed tomography), etc have all been valuable additions to the radiologist's arsenal of imaging tools toward ever more reliable detection and diagnosis of disease. Tomo graphic imaging principles are rooted in physics, mathematics, computer science, and engineering. Here, we mainly focus on the conceptual overview of the principles of MRI, one of the major imaging modalities currently in use [8].

Image processing is used mainly for : a) Enhancing images to the human observer, including their printing and transmission and b) preparing images for the feature extraction measurement. Processing and analyzing the organs being imaged in order to effectively extract, quantify and interpret information from them has been a challenge that could lead to lack of understanding and acumen of the structure and function of the images [10]. There are some of the specific challenges in medical image processing : i) Enhancing and restoring image, ii) Segmentation of the region of interest, iii) Feature extraction of the image, iv) Automated or semi-automated classification of the image, and v) Development of integrated systems for the clinical sector[9].

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Hence, this paper emphasizes on the image enhancement from the images obtained and therefore selecting the best enhancement techniques for MR images in EAH patients.

II. METHODOLOGY

This study is consisted of 2 patients with final diagnosis of EDH, SDH and SAH respectively. The images of all the patients were obtained from the database Radiopedia.org . In this study, incremental method was used whereby all the data were collected and then analyzed using the image processing techniques [7].

A. DIGITAL DATA ACQUSITION

All patients with EDH, SDH and SAH were identified respectively . A manual search was conducted to identify all the patients with EAHs based on CT imaging and to exclude patients with other types of bleed. A second search was also conducted to identify patients who have had an MRI done within 1 month or 1 year of the index CT scan.
For this study, 2 MR images each from 6 different patients that have EDH, SDH and SAH respectively , were chosen to be analyzed with 4 techniques of image enhancement which are : a) Contrast Enhancement, b) Histogram Equalization, c) Image Sharpening and d) Median Filter.

B. IMAGE ENHANCMENT TECHNIQUES

The principal objective of image enhancement is to process a given image so that the result is more suitable than the original image for a specific application. It accentuates or sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis. The enhancement doesn't increase the inherent information content of the data, but it increases the dynamic range of the chosen features so that they can be detected easily. The greatest difficulty in image enhancement is quantifying the criterion for enhancement and, therefore, a large number of image enhancement techniques are empirical and require interactive procedures to obtain satisfactory results. Image enhancement methods can be based on either spatial or frequency domain techniques. Spatial domain method can be defined as manipulating directly the image pixels to intensify the image whereby in the frequency domain method, the image is first transferred in to frequency domain, computing the Fourier Transform of the image. In this study, the spatial domain method is used for enhancing the images. The operation can be formulated as shown by the equation (1) [1].

$$g(a,b) = T[f(a,b)] \qquad (1)$$

Where $g\ (a, b)$ is the output, $f\ (a, b)$ is the input image and T is an operation on f defined by the neighbourhood of (a, b).

Several techniques were commonly used to enhance an image such as power law transformations, histogram processing, smoothing spatial filters (low pass filter, median filter) and the sharpening spatial filters (high boost filter, derivative filters). This paper focuses on the power law transformations, histogram processing, smoothing and sharpening spatial filters.

i. POWER LAW INTENSITY TRANSFORM AND GAMMA CORRECTION

Power law transformation is a gray level transformation in the spatial domain. It is conceptually similar to alpha rooting in the frequency domain as this is done by raising the input grey level by some power. It is similar in operation to the log transforms in that power law transforms with fractional values of γ map a narrow range of dark input values into a wider range of output values thereby increasing the contrast[1]. The transformation can represented as:

$$s = cr^{\gamma} \qquad (2)$$

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Based on the equation (2), where s is the output grey level, r is the input grey level, c is a scaling constant and γ is the power to which the input grey level is raised. One significant advantage of the transformation is that it is possible to control the transformation function by varying the parameter γ. In power law transformation with γ value, an image can be enhanced to become brighter and also darker. In other words, if the gamma value is less than 1, a brighter (higher contrast) images is produced and a darker image is obtained when the gamma value is greater than 1[1].

ii. HISTOGRAM EQUALIZATION (HE)

Histogram equalization is a spatial domain method that produces output image with uniform distribution of pixel intensity means that the histogram of the output image is flattened and extended systematically. This approach customarily works for image enhancement paradigm because of its simplicity and relatively better than other traditional methods. We acquire the probability density function (PDF) and cumulative density function (CDF) via the input image histogram. Apply these two functions PDF and CDF for replacing the input image gray levels to the new gray levels, and then we generate the processed image and histogram for the resultant image[1]. At first, the probability density function of the image is calculated as shown below :

$$pdf\ (X_k) or\ p\ (X_k) = n_k / N \qquad (3)$$

Where $0 \le k \le (L-1)$

L is the total number of gray levels in the image,

N is the total number of pixels in the image,

n_k is the total number of pixels with the same intensity level k.

After calculating the probability density function, the cumulative distribution function is defined as :

$$cdf(X_i) or\ c\ (X_i) = \sum_{i=0}^{k} p(X_i) \qquad (4)$$

A transform function using the cumulative distribution function is defined so that the input image can be mapped into the entire dynamic range of $[X_{0,} X_{L-1}]$ as:

$$f(X) = X_0 + (X_{L-1} - X_0) \times cdf(X_i) \qquad (5)$$

Hence, the processed image of histogram equalization can be defined as :

$$Y = f(X) \qquad (6)$$

During histogram equalization approach the mean brightness of the processed image is always the middle gray level without concerning of the input mean[1].

iii. IMAGE SHARPENING

Human perception is highly sensitive to edges and fine details of an image, and since they are composed primarily by high frequency components, the visual quality of an image can be enormously degraded if the high frequencies are

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attenuated or completed removed. In contrast, enhancing the high-frequency components of an image leads to an improvement in the visual quality. Image sharpening refers to any enhancement technique that highlights edges and fine details in an image. Image sharpening is widely used in printing and photographic industries for increasing the local contrast and sharpening the images. In principle, image sharpening consists of adding to the original image a signal that is proportional to a high-pass filtered version of the original image. The original image is first filtered by a high-pass filter that extracts the high-frequency components, and then a scaled version of the high-pass filter output is added to the original image, thus producing a sharpened image of the original[1].

$$g\ (a,b) = f\ (a,b) - f_{smooth}\ (a,b) \qquad (7)$$

where $f_{smooth}(a,\ b)$ is a smoothed version of $f\ (a,b)$. The complete un sharp masking operator is defined as :

$$f_{\ sharp}(a,b) = \ f\ (a,b) + k * g(a,b) \qquad (8)$$

where k is a scaling constant which varies between 0.2 and 0.7 with the larger values produces a sharper image.

iv. MEDIAN FILTER

Median filtering is a nonlinear process useful in reducing impulsive, or salt-and-pepper noise. It is also useful in preserving edges in an image while reducing random noise. Impulsive or salt-and pepper noise can occur due to a random bit error in a communication channel. In a median filter, a window slides along the image, and the median intensity value of the pixels within the window becomes the output intensity of the pixel being processed. For example, suppose the pixel values within a window are 5,6, 55, 10 and 15, and the pixel being processed has a value of 55. The output of the median filter at the current pixel location is 10, which is the median of the five values[1]. The equation for median filter can be defined as :

$$g[a,b] \ = \ median\{x[i,j\ ],(i,j\ ) \in w\} \qquad (9)$$

where w is the neighbourhood pixels centred around the location of $[a,\ b]$in the image.

III. PROPOSED ALGORITHM

Enhancement is the fundamental undertaking in computerized picture preparing and investigation, intending to improve the existence of image as far as human brightness observation. The main function of image enhancement is to complete the hidden part in an image and to enhance the low contrast image. The quality of the image gets better by contrast manipulation.

A. POWER LAW TRANSFORMATION IMAGE AND GAMMA CORRECTION

In power law transformation and gamma correction technique, the images were processed with different values of gamma. The best gamma value that was selected to be used later in the analysis part is the image with gamma value of 0.8 .

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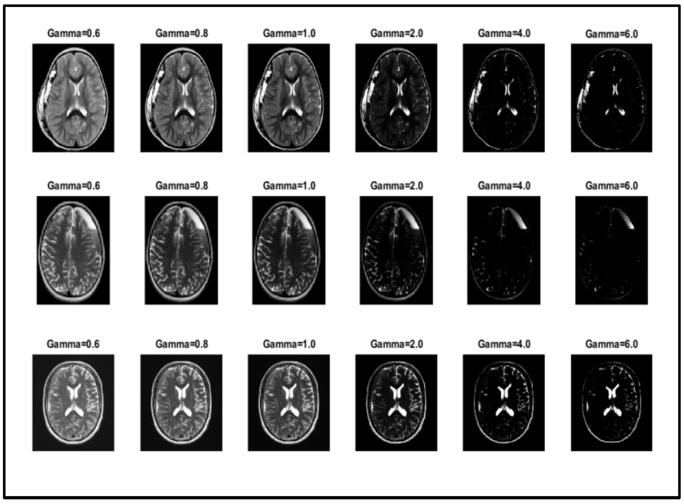

Figure 1

Gamma correction is a non-linear adjustment to individual pixel values. While in image normalization we carried out linear operations on individual pixels, such as scalar multiplication and addition/subtraction, gamma correction carries out a non-linear operation on the source image pixels, and can cause saturation of the image being altered. Furthermore, it can also lead to poor contrast if the gamma value is too large or too small. Nonetheless, it is still an important operation to cover[11].

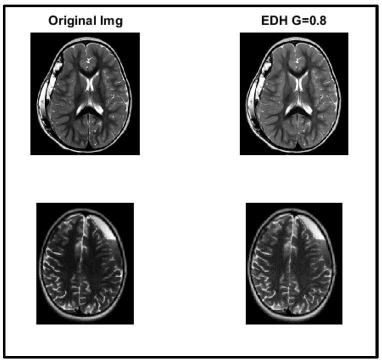

Figure 2

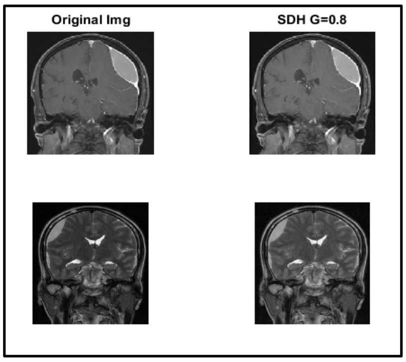

Figure 3

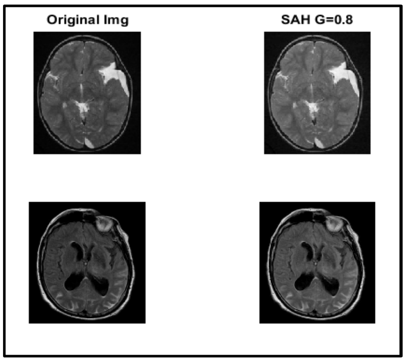

Figure 4

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B. HISTOGRAM EQUALIZATION (HE)

The objective is to map an input image to an output image such that its histogram. is uniform after the mapping[13].

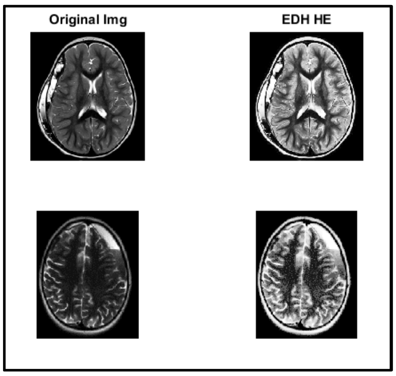

Figure 5

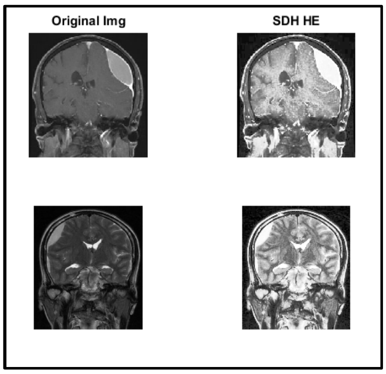

Figure 6

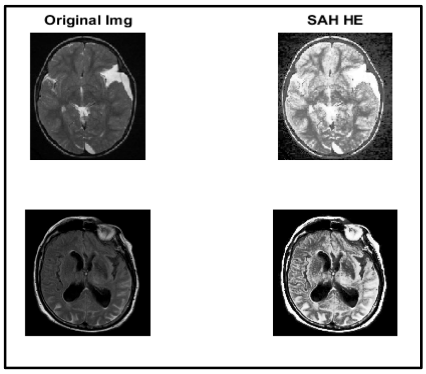

Figure 7

C. IMAGE SHARPENING

Smoothing filters are those which remove fine detail in an image. Whereas the Sharpening spatial filters seek to highlight fine detail, Remove blurring from images, Highlight edges Sharpening filters are based on spatial differentiation. Differentiation measures the rate of change of a function[14][17].
The first sharpening filter we will look at is the Laplacian Isotropic One of the simplest sharpening filters We will look at a digital implementation. The Laplacian is defined as follows:

$$\nabla^2 f = \frac{\partial^2 f}{\partial^2 x} + \frac{\partial^2 f}{\partial^2 y}$$

We can easily build a filter based on this $\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$

Applying the Laplacian to an image we get a new image that highlights edges and other discontinuities.

In order to get our final image Subtract the Laplacian result from the original image to generate our final sharpened enhanced image.

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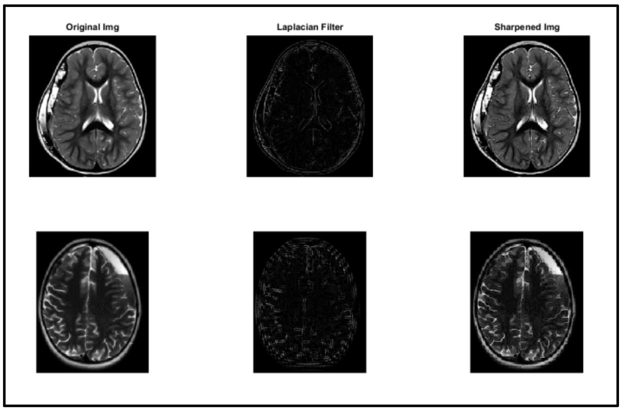

Figure 8

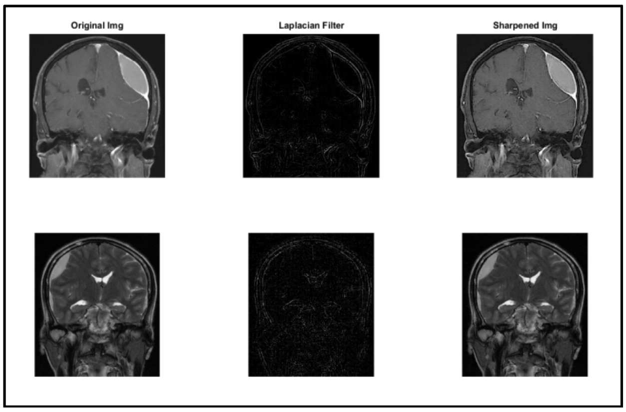

Figure 9

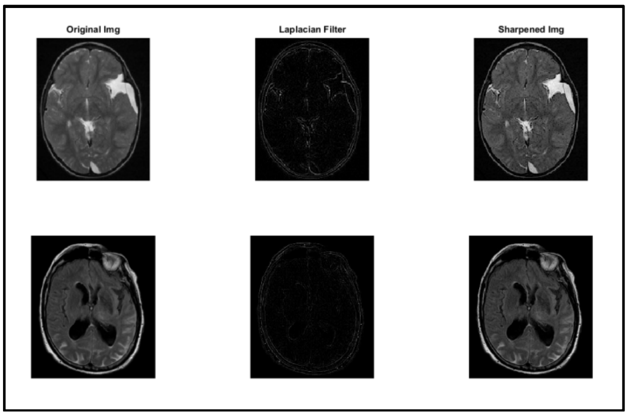

Figure 10

D. MEDIAN FILTER

The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighbouring pixels. The pattern of neighbours is called the "window", which slides, pixel by pixel over the entire image 2 pixel, over the entire image. The median is calculated by first sorting all the pixel values from the window into numerical order, and then replacing the pixel being considered with the middle (median) pixel value [19].

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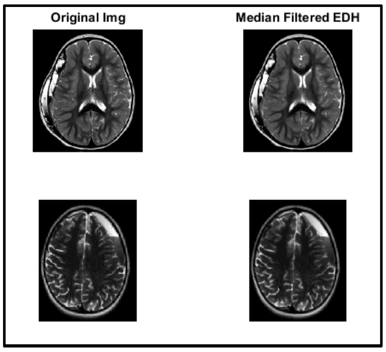

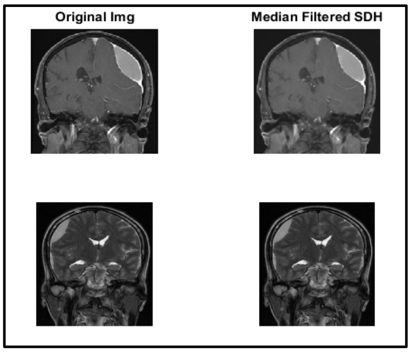

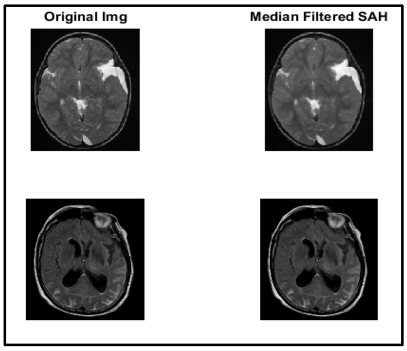

Figure 11 **Figure 12** **Figure 13**

IV. PERFORMANCE ANALYSIS OF THE PROCESSED MR IMAGES

A. AMBE

AMBE is defined as the difference between the input and output mean. The expression for AMBE may be given as $AMBE = | E(x) - E(y) |$

Where, *E(x)* is the mean of the input image, *E(y)* is the mean of the output image. A median value implies better brightness preservation .Minimum brightness error means better brightness preservation [1][13]

Table 1 : AMBE values

	Original Images	Power Law & Gamma Correction	H E	Sharpening (Unsharp masking)	Median Filter
EDH					
Img 1	0	10.98	118.5783	0.9931	0.1012
Img 2	0	11.2623	123.8319	0.9659	0.0997
SDH					
Img 1	0	10.4025	123.6366	0.9952	0.1013
Img 2	0	8.569	123.8441	0.7486	0.7565
SAH					
Img 1	0	13.7845	157.1909	0.1302	0.1325
Img 2	0	9.9059	118.8104	0.9182	0.9372

B. ENTROPY

The richness of the information contained in an image is evaluated by using entropy and is computed by :
$\text{Entropy}[p] = -\sum_{k=0}^{L-1} p(X_k)\, log_2\, p(X_k)$

Where L is the number of gray levels and ( ) *k p X* is the probability associated with gray level *k* . The increase in the value of the entropy shows that there is more information contained in the image [1][13].

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Table 2 : Entropy Values

	Original Images	Power Law & Gamma Correction	H E	Sharpening (Unsharp masking)	Median Filter
EDH					
Img 1	5.7497	5.7163	3.1829	3.6646	4.8943
Img 2	3.4296	3.4288	2.6513	2.8474	5.8605
SDH					
Img 1	6.6308	3.8168	3.3514	3.9001	6.8233
Img 2	6.7519	5.1899	4.5234	5.2202	5.2000
SAH					
Img 1	6.3491	3.1138	2.7421	3.1409	4.1222
Img 2	5.1247	3.9360	3.3256	3.8102	5.9560

From Table 1 and 2, the values of AMBE and entropy from median filter for all the MR images are much nearer to the original image. It can be deduced that median filter preserves the original brightness and also the richness of information contained in the enhanced images better than the other technique

V. CONCLUSION AND FUTURE WORK

Based on all the 4 image enhancement techniques, median filter is the best technique that can be used in enhancing MR images to be implemented later for ICH classification followed by image sharpening and power law intensity transform with gamma correction. Histogram equalization is not suitable for enhancing the MR image in this study since it corrupts the images by increasing too much of its brightness.

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