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Resonance Image Enhancement using Hybrid Center Weighted Median Filter and Bacteria Foraging Optimization

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Abstract: Magnetic Resonance Image (MRI) is the best imaging technique employed nowadays for diagnosing brain tumour in the initial stage. This paper recommends an unique method for the brain MR image enhancement, that is centred on the Hybrid Center Weighted Median (HCWM) filter and Bacteria Foraging Optimization (BFO). The MR image for this research is obtained from the online and it is pre-processed to remove all the film artifacts. After that the high frequency components are eliminated from the MR brain image by means of a newly proposed HCWM filter. HCWM Filter is the hybrid filter derived by combining the Center Weighted Median Filter and the Weiner Filter. The swarm-based intelligence algorithm called the bacteria foraging optimization is used to predict the weights of the filter dynamically. The performance of the proposed filtering approach is evaluated with the other available filtering methods.

Keywords: Magnetic Resonance Image, Brain Tumor, Image Enhancement, Hybrid Center Weighted Median Filter, Bacteria Foraging Optimization

I. INTRODUCTION

As per the American Brain Tumor Association (ABTA), around 16,000 people expected to lose their life due to brain tumor during the year 2019. The most commonly prevailing type of brain tumor are Meningioma, Glioma, Glioblastoma etc. [22]. According to GLOBOCAN, during the year 2018 the estimated number of newfound brain cancer cases will be 2,96,851 and 2,41,037 brain cancer deaths are expected in the same year [26].

For analyzing the MR brain images, the raw image ought to be pre-processed to eliminate the artifacts, labels and the skull regions. Various types of image processing systems[1] [4-6] [20] are available for image enhancement, segmentation, classification and recognition.

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Image enhancement also involves with the following processes like contrast adjustment, noise removal, filtering etc. [9][15]. Enhancement also includes the efficient removal of unwanted portions of the image using tracking algorithm [8][14].

A comprehensive survey about brain image enhancement is done in [3][11][19][27][28][29-32], where all the spatial and frequency domain enhancement techniques are analyzed.

Weighted Median (WM) filter is a form of median filter that uses both the rank based information and the spatial information of the image. The variant of the WM filter is the Center Weighted Median (CWM) filter, which is easy to implement and also it can be understood theoretically in an easy way [15]. This work proposes an innovative Hybrid Center Weighted Median Filter to enhance the brain MR image. Center Weighted Median (CWM) filter which is very simple and perfect.

The HCWM filter dynamically changes the weight using the swarm based optimization algorithm known as the bacteria foraging optimization which was put forward by Passino. The BFO algorithm is based on the swarming characteristics of real E. coli bacteria. The Bacteria explore for the food and nutrients in such a way to exploit the energy acquired per unit time. The E. coli bacterium can perform a tumble or swim during the time of foraging. The basic operations performed by the bacteria include chemotaxis, swarming, replication, elimination and dispersal [25].

This research paper is arranged with 4 sections: section 2 portrays image acquisition and pre-processing techniques, section 3 presents the enhancement technique using HCWMF for the MR images, section 4 provides the experiment results and conclusion.

II. METHODOLOGY

The overall process starts with the collection of brain MR images from the standard databases. The collected images should be pre-processed to remove the artifacts. Various available filtering techniques along with the proposed HCWM filter is applied on the pre-processed images. The weights in the proposed filters were dynamically adjusted using the BFO algorithm. Various error and enhancement parameters were used to find the efficiency of the proposed filtering technique.

The whole work is implemented and tested using Matlab tool, which is the post popular and commonly used tool for image processing applications

III. BRAIN MAGNETIC RESONANCE IMAGE ACQUISITION AND PRE-PROCESSING

A. Brain magnetic resonance image acquisition

The dataset required for this research work is a collection of brain MR images that consist of tumor and some without tumor. Getting the data from the patients or hospitals will be a tedious process which involves privacy issues. So the brain MR images data were taken from the brain web catalogue of the Harvard Medical School [23] and the McConnell Brain Imaging Center (MBIC)[24]. A random sample of 200 MR images (T1 weighted) was extracted from the mentioned web databases for this research work. The main reason for selecting the T1 weighted images is that they show the fat regions much brighter than the fluid parts of the brain. The raw images obtained from the database are in an image format called MINC. These images are transformed to the JPEG format before performing the pre-processing steps. All the images considered here are the axial view grayscale images with slice thickness of 1 mm and size of 256 x 256. The contrast of some of the images considered were enhanced with the contrast agent called Gadolinium

B. Pre-processing

The pre-processing operation starts with the removal of the film artifacts using the well-known tracking algorithm. This algorithm is used for efficient removal of film artifacts without disturbing the pixels on the MRI. Poor power quality is a foremost contributor to MR image artifacts. Power irregularities such as spikes, surges, sags and unwanted electrical noise all are a factor in the inaccurate detection, processing and display of images in MRI systems [18].

The tracking algorithm generates the intensity histogram from the first row and first column. The algorithm will analyse all the pixel intensity values and will find the base value of the image artifact. After finding the base value, the pixels with intensity above the base value is eliminated from the image. In addition to the noise removal, the algorithm separates the brain area, including the skull from the background of the MR image.

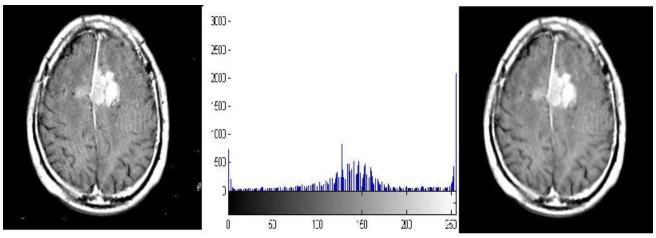

Figure. 1 Output generated from preprocessing
(a) Input image (b) Pixel intensity histogram
(b) Output image

Figure. 1 demonstrates the output obtained after applying the tracking algorithm. Figure. 1(a) is the raw image obtained from the online database and the different threshold levels are obtained using the image histogram given in Figure. 1(b). Region growing algorithm is applied for the binary image by using the selected threshold and the pre-processed MR image is obtained as shown in Figure. 1(c).

IV. MAGNETIC RESONANCE IMAGE ENHANCEMENT

Applying the enhancement techniques on MR brain image ensures to enhance the brain images for further analysis. Some of the commonly used enhancement techniques include the low pass filter, high pass filter, median filter, Weiner filter etc. [7] [10].

In the enhancement stage the filters are devised to enhance the facade of images, mainly by sharpening edges, corners, and line detail. Quite a lot of new enhancement filters also integrate a noise-reduction component. The main reason for noise that degrades image information in any MR image is from the patient's body because of the radio frequency emission produced due to the thermal motion [13].

The proposed system shows the application of the hybrid center weighted median filter on MR brain images for removing high frequency components and to enhance it. The results of the enhancement are evaluated with the existing median filter and the weighted median filter.

A. Median Filter

Median filter is a primitive type of filter used to minimize the noise in a digital image without disturbing its features. The new intensity of the current pixel is found by calculating the median of its neighbouring ones. This procedure of calculating the median is carried out throughout the image so that the high frequency components are eliminated from the image [12].

For each pixel in the MR image, three different windows of size 3, 5 and 7 neighbourhood pixels are selected. The pixel intensity values inside each window are sorted in order to obtain the median value. The pixels in every window will be substituted with the calculated median value. The same technique is applied for the whole brain MR image to enhance it.

B. WM Filter

A WM filter is controlled by the unification of the weighted mask over the image for eliminating the noise from the images. WM filtering is a type of enhancement method for eliminating noise without considerably changing the sharpness of the images by sustaining the edges [5]. The weighted median value W(x, y) is calculated as shown in equation (1)

$$W(x, y) = \text{median}\,\{w_1 \times p_1 \ldots\ldots\ldots w_n \times p_n\} \qquad (1)$$

where, $p_1 \ldots\ldots p_n$ are the pixel intensity values inside the window centered at the position (x,y) with the assigned weights $w_1 \ldots. w_n$.

The process of assigning weights to each pixel in the window is centred on the pixel intensity in the brain MR image. For the filtering technique, the following are the weights with the values 0, 0.1, 0.2 and 0.3 were used. If 0 is the intensity of the pixel then the assigned weight is 0, else if it is between 1-100 then the weight is 0.1, else if it is between 101-200 then the weight is 0.2, else the pixel weight will be 0.3 [17].

The window with size 3, 5 and 7 are considered for this purpose. For every window of pixels, the weights are multiplied by intensity of the pixel, then the median filter is utilised for calculating the median value and it is set to the center pixel

C. Brain MR Image Enhancement using HCWM Filter

- CWM Filters

The Center Weighted Median (CWM) filter is the simplest among the WM filters. The concept of the CWM filters is to assign more weight especially to the pixel in the central position of each selected window. The main advantage of the CWM filter is that it is able to retain the very fine particulars of the image and by controlling the additive and impulsive noises [16].

A CWM filter is expressed by two factors which includes the size of the window and the weight of the center pixel. A CWM filter with N pixels and center weight K is denoted by CWM (N; K)..

- Weiner Filters

Wiener filter is the best technique for elimination of the blur from the digital images which are caused due to linear motion or unfocused optics [2]. Wiener filter applies statistics including the mean and variance of the neighbouring pixels to approximate the current pixel value. The formula to calculate the mean and variance is given by the equations (2) and (3).

$$\mu = \frac{1}{NM} \sum_{n_1, n_2} x(n_1, n_2) \qquad (2)$$

$$\sigma^2 = \frac{1}{NM} \sum_{n_1, n_2} x^2(n_1, n_2) - \mu^2 \qquad (3)$$

where the image is defined as x with the size N x M
The filtered output is given by equation (4)

$$y(n_1, n_2) = \mu + \frac{\sigma^2 - E\xi^2}{\sigma^2}(x(n_1, n_2) - \mu) \qquad (4)$$

the filtered image is termed as y, E is the error rate, μ represents the mean of the selected region, σ defines the standard deviation and ξ is a constant value 1

- HCWM Filter

Since the MR brain images have additive white and impulsive type noise also with slight blurring, it is better to combine the approaches of enhancement. The main objective is to preserve image details along with its fine edges [18]. First the brain MR image is filtered using the center weighted median filter CWM (M; 2K + 1), where the value of K is dynamically calculated every time using the simplified bacteria foraging optimization algorithm. This value of K determines the efficiency of the enhancement algorithm.

Bacteria are placed on the different weight values; the movement of the bacteria either by swim or tumble will move it to the next solution. Later in the chemotaxis step the bacteria use the fitness function to assess the best solution and therefore the best weight value is computed. Once the image is filtered with the modified CWM filter, again it is filtered once again by the Wiener filter to produce the super quality image without noise. The HCWM filter is demonstrated in the below given Figure. 2

Due to the first phase of filtering using the CWM filter most of the additive and the impulse noises are removed, still it is fair to remove the blurriness from the image. This minute blurring effect was corrected by the Weiner filter. The brain MR image is filtered with different window of sizes 3, 5 and 7.

The following steps explain the process of finding out the weight value K for the hybrid center weighted median filter using the BFO algorithm. For every window region, this algorithm dynamically computes the weight value to be used in the filter. The global best value computed using the BFO algorithm will be the weight value applied to the filter.

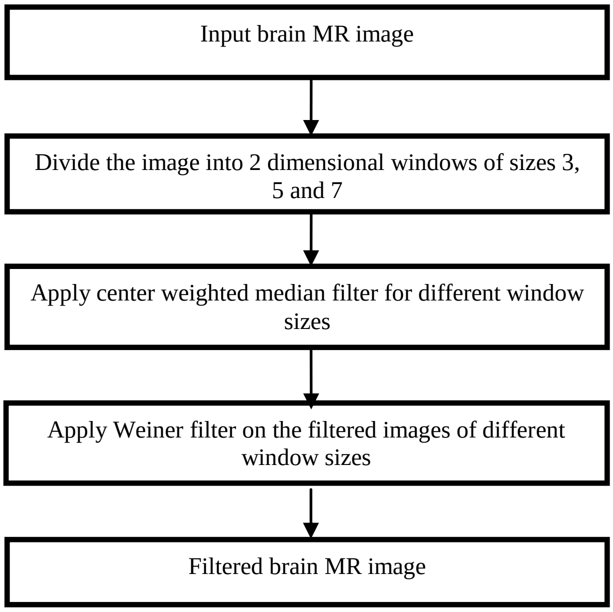

Figure. 2 Hybrid center weighted median filter

Steps to determine the value of K using BFO algorithm

Step 1. The set of random candidate weights (W) is initialized

Step 2. Each bacterium is positioned in one of the weights which represent one possible solution.

Step 3. The bacteria are initialized to the first weight and the fitness function is computed using the following circumstance

a) If the mean value of all the neighbouring pixels inside the window other than the center pixel is higher than the center pixel intensity, then the weight is calculated as given in equation (5)

$$K = \frac{\sum_{i=1}^{i \le n} Wi * \mu}{n} \qquad (5)$$

Where W_i is the random candidate weights, μ represents the mean of the selected region, n is the total pixels in the selected area and K is the calculated weight.

b) Otherwise the weight is calculated as the maximum value of W_i

Step 4. The bacteria use chemotaxis step to move or tumble to the next weight and discover the local best

Step 5. Perform reproduction based on the health of the bacteria.

Step 6. Perform elimination dispersal to keep the number of bacteria same.

Step 7. Find the global best among all the bacteria that will be the weight “K” selected from the set of weights.

V. SAMPLE OUTPUT AND PERFORMANCE EVALUATION

A. Sample output

The various filters like median filter, WM filter and HCWM filter were employed on the standard images and the outputs are given in Figure. 3.

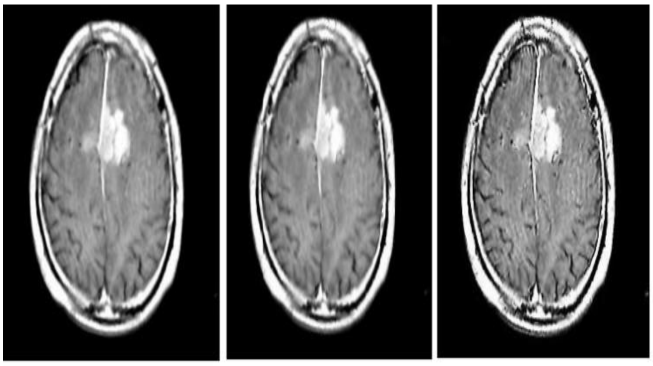

Figure. 3 (a) Filtered MR brain image using median filter
(b)Filtered MR brain image using WM filter
(c) Filtered MR brain image using HCWM filter

B. Performance Evaluation

In the case of digital image enhancement, it is extremely hard to measure the enhancement precisely or by an observer by visually observing the quality of the image. It is mandatory to measure the enhancement so as to know the performance of different enhancement algorithms. Some of the statistical criteria like variance or entropy may not be so efficient since they can measure only the local contrast enhancement [21]. The measures used for the performance evaluation are based on a ground truth reference image. These ground truth reference images are obtained from the online standard databases. The filtered images are crosschecked with the ground truth images to calculate the efficiency of the proposed algorithm. The performance of various filters was evaluated using the criteria listed below.

The whole work is implemented and tested using Matlab tool, which is the post popular and commonly used tool for image processing applications

- **Error parameters**

Mean Square Error (MSE) is calculated as the cumulative squared error among the enhanced and the original images. A low rate of MSE shows that the error is less [21].
Root Mean Square Error (RMSE) is computed by applying square root to the MSE. A lesser value of RMSE proves that the algorithm is the best [21].
Mean Absolute Error (MAE) is a standard that is utilized to assess how closely the ground truth image and the enhanced image are associated. For good enhancement the value of MAE should be less [19].

- **Enhancement parameters**

Signal to Noise Ratio (SNR) is used to compute the true positiveness of an image. It is expressed as the power ratio amongst a signal and noise. The higher this value, the sharper the enhanced image will be [9].
Peak Signal to Noise Ratio (PSNR) is a representation of the quantitative relation amongst the largest feasible value of a signal to the noise which impacts the image. A greater value of PSNR is appropriate. In PSNR, the signal is referred to the ground truth image, and the noise referred to the error due to enhancement [19].
Contrast Improvement Index (CII) is used to measure the increase in the contrast generated by the enhancement methods. If the value of CII is high, that shows the algorithm is effective. CII provides the ratio between the contrasts of the enhanced image to the original [21].
Universal Quality Index (UQI) measures the quality of the image similarity based on the various distortion types. The various distortion factors used to measure the UQI are correlation loss, distortion in luminance and contrast[19]. A high value of UQI is the indication that the enhancement algorithm is efficient.

- **Result Analysis**

The newly proposed hybrid center weighted median filter is implemented and tested with the sample 200 MR brain images. Also, the efficiency of the hybrid algorithm is compared with the existing algorithms like median filter and WM filter. Table 1 itemize the various parameters considered to evaluate the filtering techniques. The table indicates that the proposed HCWM filter has the lower error rate and higher performance indicators. For example the MAE for the proposed filter is 2.26, whereas 5.42 for WM filter and 11.53 for Median filter. Also the PSNR value of HCWM filter is 32.92 which is comparatively higher when compared to 26.22 and 20.17 for WM filter and Median filter respectively.
The performance analysis can be grouped into two, based upon the error parameters and enhancement parameters. Figure 4 provides the graphical representation of the performance of a median filter, WM filter and the HCWM filter based upon the error parameters.

Table 1 Performance evaluation of filtering techniques for brain MR images

	MSE	RM SE	MAE	SNR	PSNR	CII	UQI
Median Filter	630.26	25.1 0	11.53	1.04	20.17	1.02	0.81
WM Filter	156.38	12.5 1	5.42	3.43	26.22	1.03	0.89
HCWM Filter	33.42	5.78	2.26	5.68	32.92	1.04	0.90

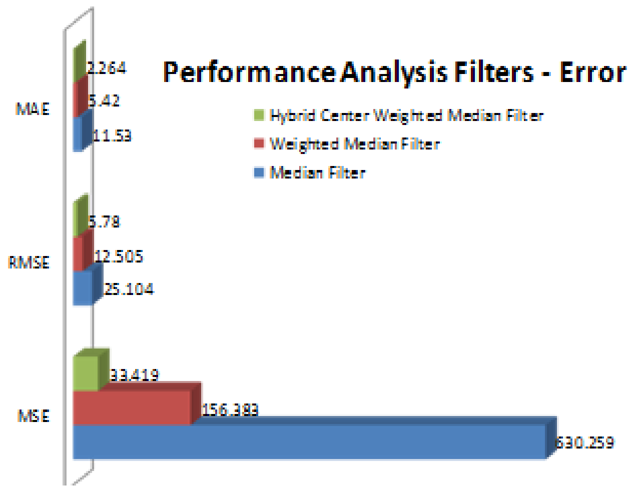

Fig. 4 Performance analyses of MR image filtering techniques – error

The prime criterion for the enhancement technique is to reduce the error due to the filtering operation applied to the brain MR image. The MSE, RMSE and MAE values for HCWMF are 33.419, 5.780 and 2.264 respectively, which are much lesser than the error values of median filter and the WM filter. From this observation, it is very clear that the newly proposed HCWM filter has very less error rate when evaluated with the other existing filters like median filter and the WM filter

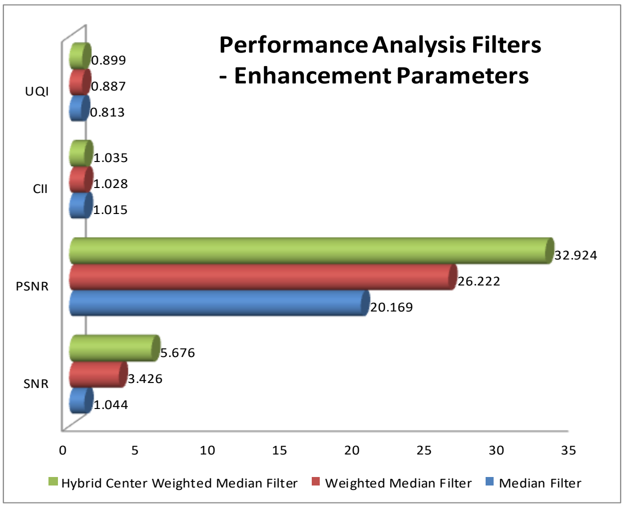

Fig. 5 Performance analyses of MR image filtering techniques – enhancement parameters

Figure 5 provides the graphical representation of the performance of various filters based upon the enhancement parameters. The enhancement parameters considered here are the SNR, PSNR, CII and UQI. The prime objective of a good enhancement technique is that the values of the enhancement parameters should be very high. The above figure clearly depicts that for the newly proposed hybrid center weighted median filter has substantially higher values of all the enhancement parameters. The newly proposed HCWM filter has SNR value 5.676, PSNR value as 32.924, CII value as 1.035 and UQI value as 0.899. These values are much higher when compared with the values of the median filter and the WM filter. Thus the observation reveals that the hybrid center weighted median filter performs the best enhancement of the brain MR images.

VI. CONCLUSION

This paper proposes an innovative enhancement technique called hybrid center weighted median filter for the quality enhancement of the brain MR images. The entire paper highlights three basic steps which involve brain MR image acquisition, pre-processing and enhancement of the proposed system. The standard brain images are acquired from the standard online databases and converted to the JPEG format for further processing. After pre-processing the images are filtered using three filters such as median filter, WM filter and HCWM filter which are used to eliminate high frequency components and the blurriness from the brain MR images. The weight calculation in the hybrid center weighted median filter is performed by using the bacteria foraging optimization algorithm. The performance of the proposed system was investigated with the currently available filtering methods. The result proves as evidence that the hybrid weighted median filter outperforms other filtering techniques.

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Second Author profile which contains their education details, their publications, research work, membership, achievements, with photo that will be maximum 200-400 words.

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