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Adaptive Image Enhancement Using Hybrid Particle Swarm Optimization and Watershed Segmentation

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ABSTRACT
Medical images are obtained straight from the medical acquisition devices so that, the image quality becomes poor and may contain noises. Low contrast and poor quality are the major issues in the production of medical images. Medical imaging enhancement technology gives way to solve these issues; it helps the doctors to see the interior portions of the body for early diagnosis, also it improves the features the visual aspects of an image for a right diagnosis. This paper proposes a new blend of Particle Swarm Optimization (PSO) and Accelerated Particle Swarm Optimization (APSO) called Hybrid Partial Swarm Optimization (HPSO) to enhance medical images and also gives optimal results. The work starts with (i) watershed segmentation followed by (ii) HPSO enhancement algorithm. The watershed segmentation is a morphological gradient-based transformation technique. The gradient map of an image has different gradient values corresponds to different heights. It extracts the continuous boundaries of each region to give solid results and intuitively provides better performance on noisy images. After segmentation, the HPSO algorithm is applied to improve the quality of Computed Tomography (CT) images by calculating the local and global information. The transformation function uses the calculated information to optimize the medical image. The algorithm is tested on a real time data set of CT images, which were collected from MIT-BIH dataset and the performance is analyzed and compared with existing Region Merging (RM), Fuzzy C Means (FCM), Histogram Thresholding, Discrete Wavelet Transformation (DWT), Particle Swarm Optimization (PSO), Artificial Bee Colony (ABC), Histogram Equalization (HE), Contrast Stretching and Adaptive Filtering based on PSNR, SSIM, CII, MSE, RMSE, BER and Execution time parameters. The experimental result shows that the proposed medical image enhancement algorithm achieves 96.7% accuracy and defeat the over segmentation problem of existing systems.

KEY WORDS: Medical images, Enhancement, Segmentation, Watershed, Particle Swarm Optimization, CT images, Median filter.

1 INTRODUCTION

IMAGE enhancement is a conversion of image quality to improve and more understandable level for feature extraction or image elucidation, while radiometric correction is to reconstruct the physically calibrated value from the observed data. Image enhancement techniques can be divided into four types, point operation, spatial operation, transformation and pseudo coloring defined by R.C. Gonzalez, et.al. (2009). The medical images are probably affected by its contrast, illumination, noise; due to these issues, the diagnosis of disease becomes difficult. Medical images especially CT scanned images are blocked by additive noise and may affect in the form of dense tissue to create an image. Due to this degradation, the image quality of soft tissue becomes poor. Medical image enhancement is the better solution for these issues; it is improving the information in an image and removes unwanted features. The modalities are in the medical field are X-Ray, CT, Magnetic Resonance Imaging (MRI) and Ultrasound referred by N. Mohanapriya, et.al. (2014) and Raihan Firoz, et.al. (2016).

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Before enhancement here using watershed segmentation technique to extract the continuous boundary of each region to give a solid result which requires low computation and performs well with noisy images, which is a mathematical morphological method for image segmentation based on regions. Watershed algorithm is to transform from the gray level image into its topographic depiction which consists of three essential designs: minimal value, catchment basins and watershed lines. And the topographical surface has the following conditions: (1) position belongs to different minimum level; (2) next position is, the water which falls with certainty to a single minimum; and (3) points at water can have an equally likely to fall with more than one minimum denoted by Niket Amoda, et.al.(2013). The PSO presents a population based searching procedure in which individuals are known as particles and it can adjust their position with time. In this system, particles fly around in multidimensional space and particles can adjust its location to its own experience. And also it can choose its position and its neighbors.

PSO algorithm is to maximize the content of the image with intensity transformation function and it is a combination of local and global searching. The PSO is a better way to enhance the digital images with less computation time and also it provides an optimal solution denoted by Swagat Kumar Behera, et.al. (2015).

Spatial domain image enhancement algorithm is performed based on direct manipulation of the pixel in an image. The HPSO algorithm is applied to a segmented image of CT scanned images; it is produced by measuring the attenuation along rows and columns of a matrix. The rest of the paper is organized as follows: In Section 2, literature review related with proposed algorithm. In section 3, proposed work with HPSO is discussed. In section 4, is about Result and discussion. Finally, in section 5, Conclusion of the work is made.

2 RELATED WORK

MEDICAL image enhancement is a great challenge in medical imaging technology, various algorithms used to enhance the medical images.

Lamia Jaafar Belaid, et. al. (2009), implemented a segmentation algorithm using watershed transformation; in this mathematical operators were used with asymptotic analysis which provides the location of edges. The topological gradient is used as a tool for detecting edges and morphological Laplacian is calculated for image restoration. It improves the numerical results of image segmentation problem and resolves the de-noising problem. The next segmentation is improved watershed transformation is proposed by J. Mehena, M. C, et.al. (2015), which is used for tumor extraction in Magnetic Resonance Images. Initially the segmentation function is computed, then next calculates the foreground within the object and background markers are not part of an object and finally, the watershed transformation is computed. This extraction involves detection, recognition, localization of tumor and also finding the size of tumor using marker controlled watershed segmentation. Ahmad El Allaoui, et.al. (2012), presented a segmentation algorithm using watershed markers and morphological operation. It is able to segment real medicals images.

G. Park, et.al. (2008) implemented a Histogram equalization technique; here enhancement is done by using the graphical representation of intensity values on X-axis and a total number of pixels in Y-axis. The difficulty with this technique is, not able to improve all parts of an image. The next enhancement algorithm is multilevel contrast stretching is proposed by N. Mohanapriya, et.al. (2015), it is to improve the quality and contrast by stretching the neighboring pixels. The low contrast image is divided into object approximation which is selected by inter-object level and the error image chooses by intra-object level.

Hanan Saleh S., et.al. (2016), presented a median filter for removing noise from images followed by unsharp mask filter. The Medical images are typically poor in quality and low contrast; to improve the image quality using the Contrast Limited Adaptive Histogram Equalization (CLAHE) algorithm deals medical image enhancement; here different parts of body tested and the median filter used to remove the noise. Abhijeet Ranjan, (2012), presented the Adaptive Alpha Trimmed Mean Filter and Double window Modified trimmed mean filter algorithm. Which is to enhance a CT Scanned images, initially noises removed using Alpha trimmed mean filter then edges were preserved without any lines by modifies trimmed filter.

The next is medical image enhancement using Genetic Algorithm (GA) and the Morphological filter applied by B. Lakshmi, et.al. (2012), which is to sharpen the detected edges thus improving the contrast of the image. A Genetic algorithm is analyzed and implemented by an enhanced filter to improve the computation times considerably. Enhanced image processing for a blurred image using GA based image extraction proposed by V. Premchandran, et.al. (2016). It is to retrieve the de blurred image and its depth map by only using information from the single blurred image. Here the image depth included and it is related to the spatial extent of a blur. The de blurred image and depth map is then estimated variation by means of gradient descent. Taranbir Kaur, et.al. (2016), Proposed an enhancement algorithm which is based on fuzzy with histogram enhancement, the objective of this algorithm is to improve the visibility of an image by calculating the value of amplification factor. The results are compared with different parameters against constant value and which is tested for common images only.

The next enhancement algorithm using particle swarm optimization presented by M Venkata Srinu, et.al. (2012), which improves the image quality by maximizing the content of an image. The goal is to resolve the optimization problem and it is obtained by using parameterized transformation function with the objective function. This work mainly focuses on general images than the medical images. The PSO system and challenges are proposed by Dian Palupi Rini, et.al. (2011). Which describes the basic variant PSO and modified variant PSO, and its comparison along with its advantages, disadvantages, applications. By analyzing the literature, it can be concluded that major issues in the image enhancement algorithms are accuracy, optimization and low contrast which is resolved in proposed work.

3 PROPOSED SYSTEM

3.1 Overview

THE proposed algorithm for enhancement of CT Scanned images consists of different processes which are shown in Figure 1.

Noise can be removed from an in input CT image using a filter, watershed segmentation is to segment the input images which is shown in Figure 2 then enhance the segmented image using Hybrid Particle Swarm Optimization algorithm and resulting in enhanced image used for detecting and classification of tumors.

3.2 Noise Removal-Median Filter

Medical images directly obtained from acquisition devices so it contains noises and other artifacts. Before applying enhancement algorithm need to remove the noise in an image. Median filtering is a better solution to remove the outliers without reducing the sharpness of an image. The initial step is to calculate the median value of each block and the noisy pixel is replaced with that median values. If the neighborhood is middle element then the block replace the median value of the pixel. It also performs median filtering of the matrix of two dimensions.

This approach is based on watershed transformation with gradient method. The segmentation process consists of two major steps: (1) to detect the major edges of the degraded image, (2) to compute the topological watershed of the gradient detected. This segmentation algorithm takes minimum computational time and provides better results.

CT image is split into a number of edges and regions then each region considered as a topographic surface which is having the following steps:

I. Position to indicate the regional minima
II. Position to falling has the highest probability of fall into single minima region
III. Position to falling has the highest probability fall into more than one such minima region.

If a group of position satisfies the second step called watershed basin of the minimum. If satisfy the third step, makes a summit line on topographic surface termed as a watershed line. Based on the above steps the following process to be done,

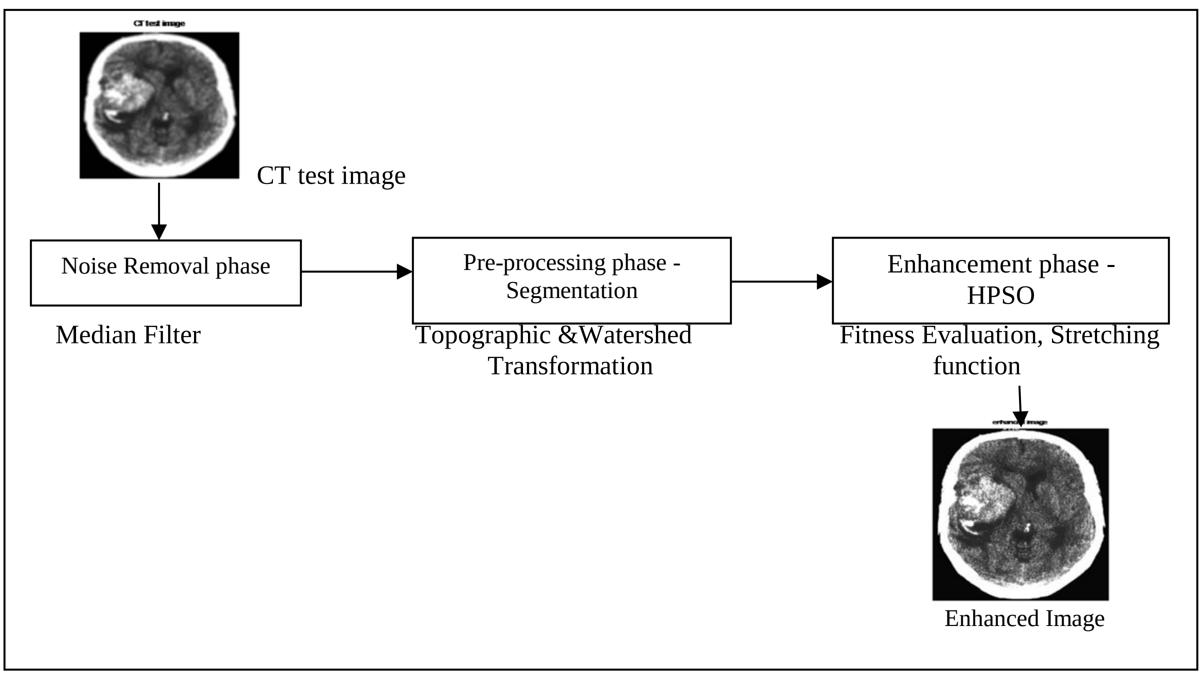

Figure 1. Illustration of Proposed Hybrid Particle Swarm Optimization Enhancement

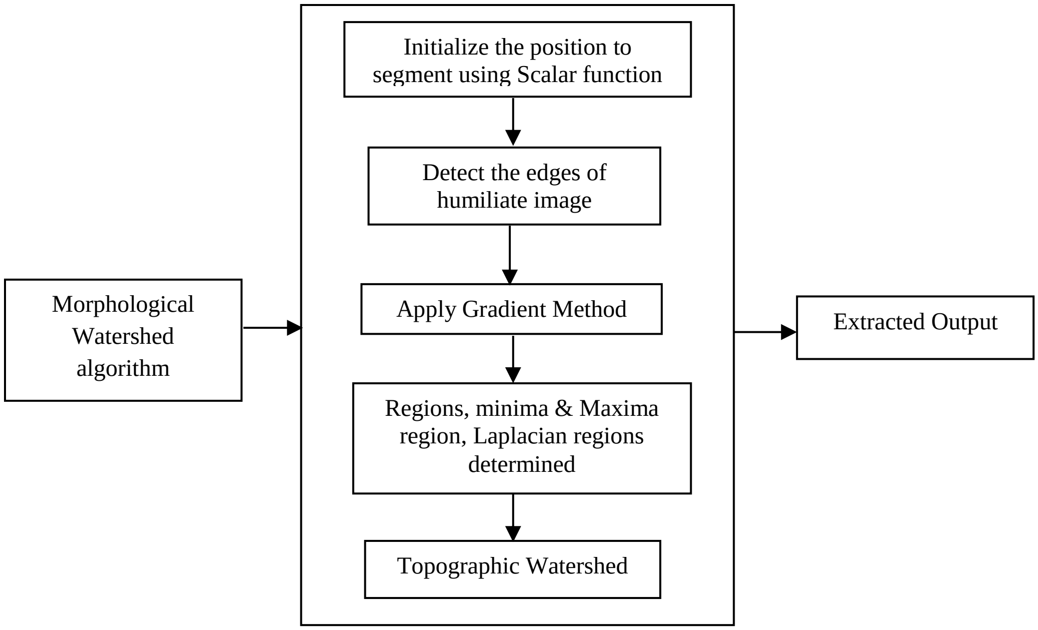

Figure 2. **Block diagram for proposed segmentation algorithm**

Let I is the input CT image,

- I(x,y) –Pixel representation of image I
- s(x,y) - Subset of domain E.
- R - Region of I,
- δ - watershed gradient operator of an image I, defined by the scalar function,

$$\delta_E s = \left(s \bigoplus E\right) - (s - E) \quad (1)$$

where, $s \bigoplus E$ - Dilation of s by the element of R and $s - E$ - Erosion of s by the element of R.

To find minimum and maxima values in regions calculate morphological laplacian,

$$\Delta_E s = (s \bigoplus E - 2s + (u - E)) \quad (2)$$

Here, the regions with $\Delta_E s < 0$ then it is considered as in the maxima, the regions with $\Delta_E s > 0$ are to be minimal, if $\Delta_E s = 0$ then have to interpret the edge locations. It is useful to represent essential property for construction of morphological operations. After finding laplacian, have to decide whether apply dilation or erosion to the input image, depending upon whether the pixel located in minima region or in maxima region.

Now to calculate the topological gradient from the following equation,

$$G(x, n) = (M(x)n, n) \quad (3)$$

where, G - Gradient, M(x) - Symmetric matrix, n is an eigenvector.

After finding gradient, the eigenvector can be associated with the lowest eigenvalue of Matrix M. the same method is applied to all M × N of the image. And it is considered as the topological gradient which is associated with the optimal orientation of the crack and it is simulated by a small constant value (c).

Algorithm:

I. The topological gradient algorithm initialized by c as c_0,
II. By using above equation to find the gradient,
III. Compute an image into the matrix and find the lowest eigenvalue at each point of the domain.

Using equation (1) & (2), a comparison is done with constant value, these steps repeated until all regions of an image have segmented. Here CT medical image segmented by topological watershed with gradient method, it provides more global analysis than other gradient segmentation algorithms, it preserves edges, improves image sharpness.

3.3 Hybrid Particle Swarm Optimization

The PSO initialized with the population of random solutions and searches for optima by updating generations. However, unlike GA, the PSO has no operators such as crossover and mutation. For each iteration, all particles are updated by the best values called pbest and gbest. These two best values are responsible for forcing particles to progress to the new better position. After finding the two best values, the particle updates its velocity and positions.

HPSO is to produce an enhanced image by using global and local information of input image with fitness function to find best (gbest and pbest) value of each particle.

Implementation Steps:

Step 1: Initialization:
for each particle 1 to N,
P - Population size,
N - Number of particles,
d- dimensions of the particle.
Initialize the parameters for all particles a, b, c, k

Step 2: Find local and global fitness: pbest and gbest:
l(i,j) – local mean of (i,j)th pixel of image.
(m * n) – Segmented image window size,
f(x,y) – enhancement function
Local mean calculated from the following equation,

$$l(i,j) = \frac{1}{m*n}\sum_{x=1}^{m}\sum_{y=1}^{n} f(x,y) \quad (4)$$

Next find the global information from input image,

$$g = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N} f(i,j) \quad (5)$$

g – global mean, M * N – input image window.
From the above equation, (4) and (5) found pbest and gbest.

Step 3: Update velocity and population for all particles and update the particle position by adding velocity to the current position from the following equation,

$$x_i(t+1) = x_i(t) + \upsilon_i(t+1) \quad (6)$$

$$\upsilon_i(t) = \upsilon_i(t-1) + c_1 v_1(localbest(t) - x_i(t-1) + c_2 v_2(globalbest(t) - x_i(t-1)) \quad (7)$$

Where, $x_i -$ position of particle i, $t -$ Searching time, v_1 & $v_2 -$ Random vector
$\upsilon_i -$ Velocity of particle i , c_1 & $c_2 -$ acceleration coefficient

Step 4: Evaluate fitness function of updated population using standard deviation(σ)

$$\sigma(i,j) = \sqrt{\frac{1}{m*n}\sum_{x=0}^{m}\sum_{y=0}^{n}(f(x,y) - l(i,j))^2} \quad (8)$$

If the maximum of pbest is greater than gbest then set gbest to max(pbest).

Step 5: Generate an enhanced image by using contrast pixel stretching transformation function,

$$t(i,j) = \frac{g.k}{\sigma(i,j)+b}\left(f(i,j) - c * l(i,j)\right) + l(i,j)^a \quad (9)$$

$t(i,j) -$ enhancement function
These parameters are to produce variations in an image. The range of parameters has taken from [0.01] to [2]. And also fix the maximum and minimum velocity. l(i,j) & g(i,j)- local & global mean. Low contrast, blurred image, low-quality images are enhanced using the above equations.

Step 6: Repeat the above steps for all particles 1 to P and update velocity for every iteration.

The above procedures can apply to all segmented region of a CT image. Finally, the enhanced image received from contrast stretching transformation function. The output medical image is improved in quality, better optimization elucidation and free from additive noise.

4 EXPERIMENTAL RESULTS AND DISCUSSION

THE optimization problem is considered here and resolves the enhancement problem using HPSO. The proposed work tested for CT scanned images of different body parts, which are accessed from MIT-BIH medical image dataset and it is implemented using MATLAB 8.4.

The Figure 3 shows that results of proposed algorithm and the performance evaluated with some of the existing techniques using the parameters which are shown in Table 1 and Table 2.

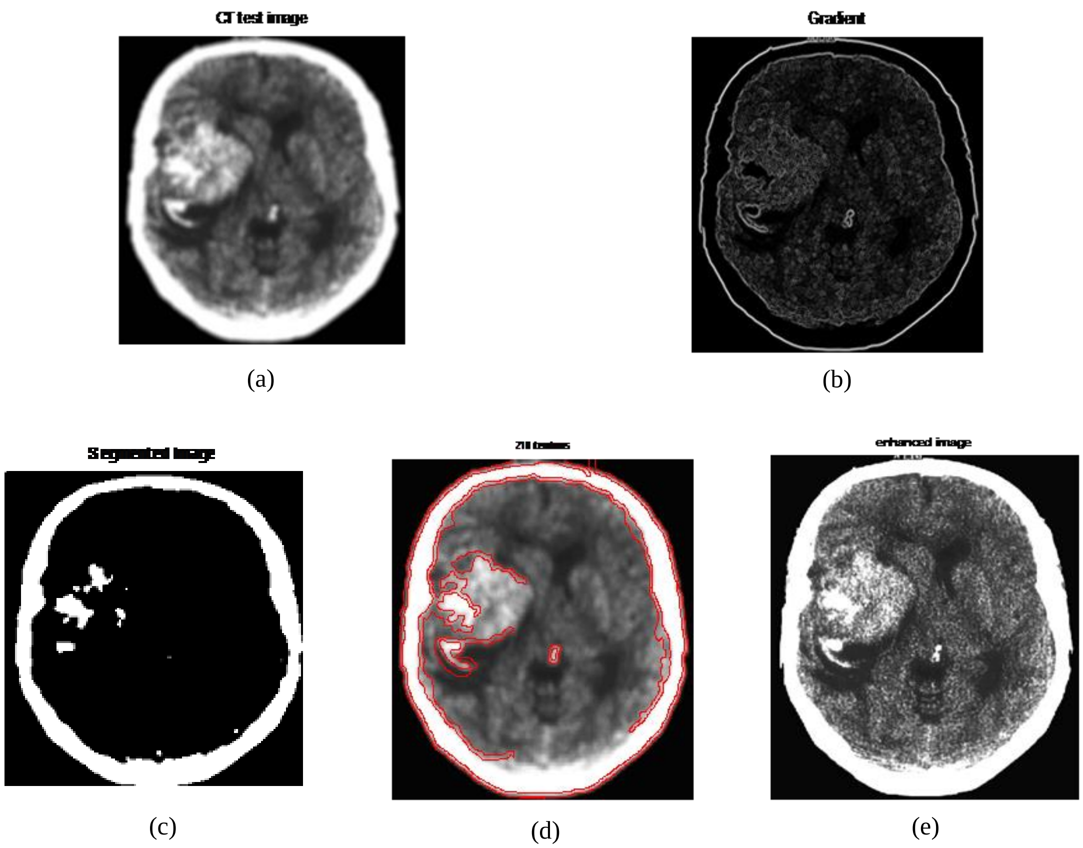

Figure 3. Results of Proposed System (a) CT Input Brain Image; (b) After gradient method; (c) Segmented Image; (d) Particle Iterations; (e) Final enhanced image

Table 1. Performance Evaluation of Segmentation algorithms

Segmentation Techniques	MSE	RMSE	BER
RM	29.0478	5.3896	0.3386
FCM	32.9567	5.7407	0.1942
Histogram Thresholding	21.6350	4.6513	0.4832
DWT	18.0484	4.2483	0.1728
Proposed Method	14.6432	3.8266	0.0153

4.1 Results

The result shows that, the CT brain image in each stage which is enhanced after the application of HPSO and watershed segmentation.

4.2 Parameters Evaluation

The performance evaluation Table 1 and Table 2 illustrates the analysis of proposed segmentation and enhancement techniques with existing algorithms with different parameters like PSNR, SSIM, MSE, RMSE, CII, BER and Execution time.

4.2.1 Mean Square Error (MSE)

MSE is to compare the true pixel values with an original image with degraded or noisy image, which is denoted by k (n, m) & k' (n, m) and it calculates the average of the squared error as:

$$e_{MSE} = \frac{1}{M\,N} \sum_{n=1}^{M} \sum_{m=1}^{N} \big(k'(n,m) - k(n.m)\big)^2 \tag{10}$$

where, M, N – Number of Rows and Number of Columns of the original & degraded image.

4.2.2 Root Mean Square Error (RMSE)

It is used to measure the accuracy of the image, to find the difference of predicted values(y) and original values(x) of n –prediction and calculate the standard deviation for difference values.

$$\text{RMSE} = \sqrt{\frac{\sum_{m=1}^{n}(x_m - y_m)^2}{n}} \tag{11}$$

Table 2. Performance Evaluation of Enhancement algorithms

Enhancement Techniques	PSNR (dB)	SSIM	CII	Execution Time (MS)
PSO	33.3586	0.9847	3.0643	2.5431
ABC	43.4866	0.9764	3.0561	2.1061
HE	23.3354	0.9758	2.9066	3.6733
Contrast Stretching	41.4728	0.7846	3.0456	3.9845
Adaptive Filter	12.0163	0.5376	2.7422	5.8472
Proposed Method	46.4728	0.9954	3.0862	1.0462

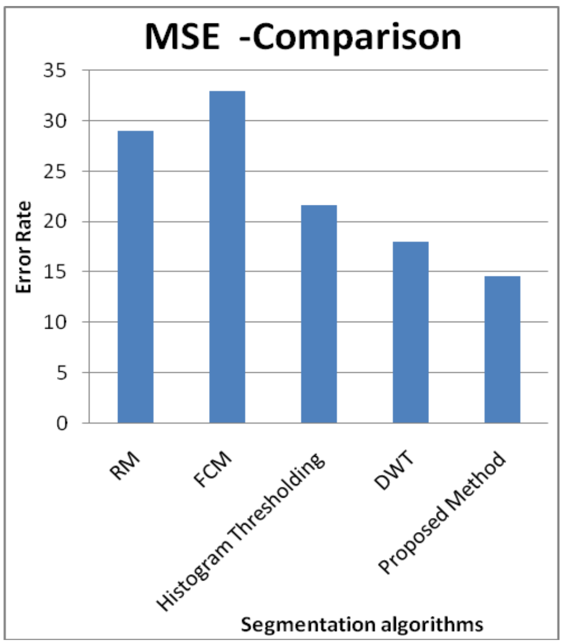

Figure 4. Comparison with Mean Square Error

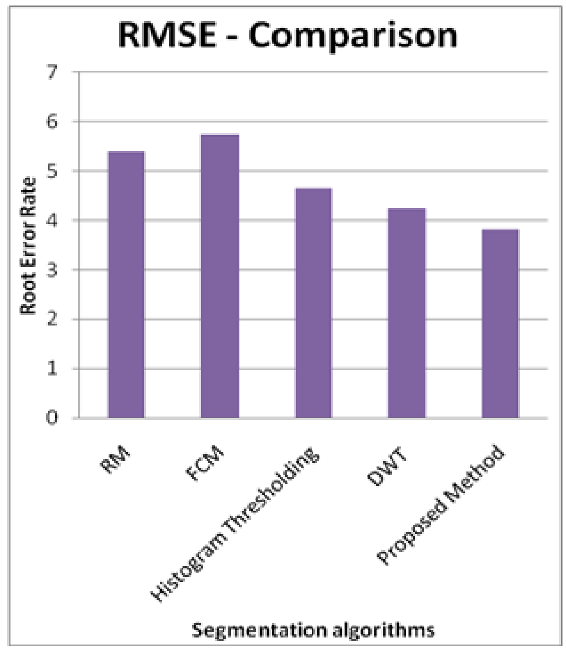

Figure 5. Comparison with RMSE

4.2.3 Bit Error Rate (BER)

The BER is calculated by, the number of bit error divided by a number of transferred bits in a scrupulous time interval.

From the results, the proposed segmentation algorithm has minimum bit error rate and mean error compared to other algorithms.

4.2.4 Peak Signal to Noise Ratio (PSNR)

PSNR is calculated in an image by taking the ratio of the highest possible values of image pixel along with corrupted image. The highest value of PSNR is to specify that the reconstruction is higher quality. The typical PSNR value range is to be between 30 and 50 dB in order to reconstruct high quality image. It can be calculated by using the following equation,

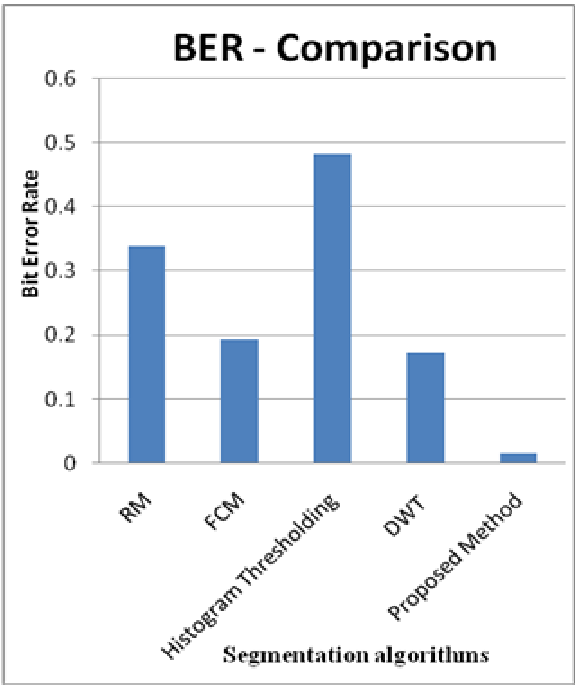

Figure 6. Comparison with Bit Error Rate

$$PSNR\ (dB) = 20\ log_{10}\left(\frac{MAX_f}{\sqrt{MSE}}\right) \qquad (12)$$

where, f – is the matrix data of original image
MSE – is Mean Square Error, MAX – is maximum signal value in original image

4.2.5 Structural Similarity Index Measure (SSIM)

Zhou Wang, et.al. (2004) referred as, the image quality is evaluated in terms of SSIM index and its recommended value is from -1 to 1. And value 1 is only reachable in the case of two identical sets of data. This quality measure based on image structure (s), luminance (l) and contrast (c) and it is computed by using the following equation:

$$SSIM(x,y) = \ (s(m,n)^{\alpha}\ ).\left(l(m,n)^{\beta}\ \right).(l(m,n)^{\gamma}\ ) \qquad (13)$$

4.2.6 Contrast Improvement Index (CII)

CII is to compare the contrast level of the images, which is calculated by taking the average of neighboring contrast of each window (C).

$$\text{CII} = \text{C}_{\text{3*3 window image}} / \text{C}_{\text{Original Image}} \qquad (14)$$

4.2.7 Execution Time

It is the time taken by the algorithm to process the image. Table 2 shows the execution time taken by different enhancement techniques on images, the result shows that the value obtained by proposed algorithm faster as compared to other enhancement algorithms.

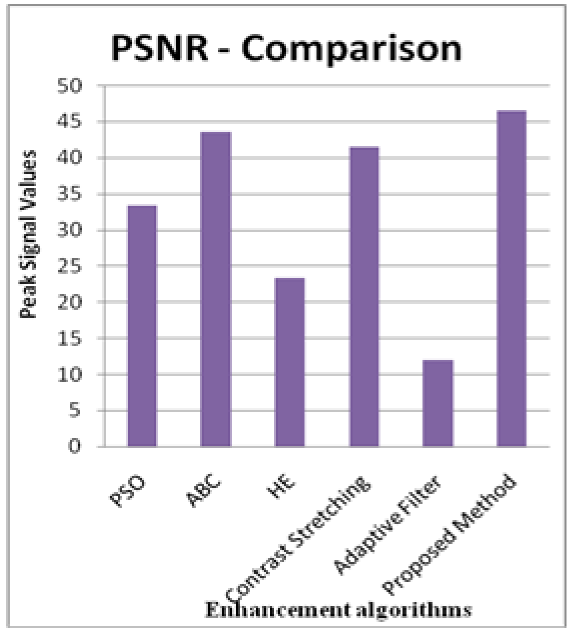

Figure 7. Comparison with PSNR

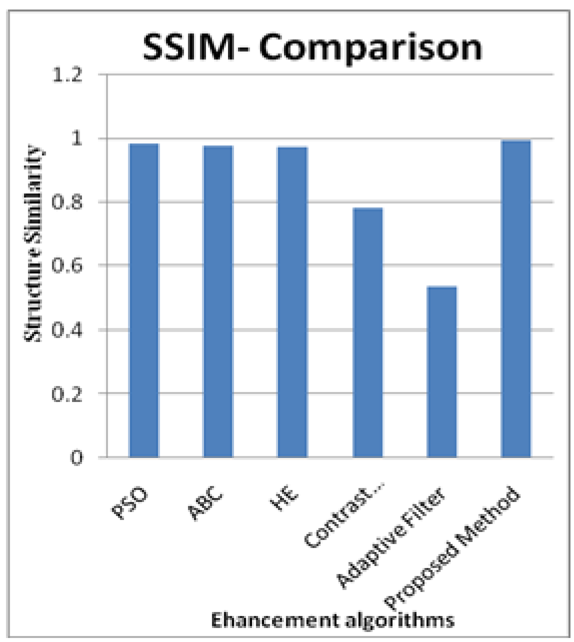

Figure 8. Comparison with SSIM

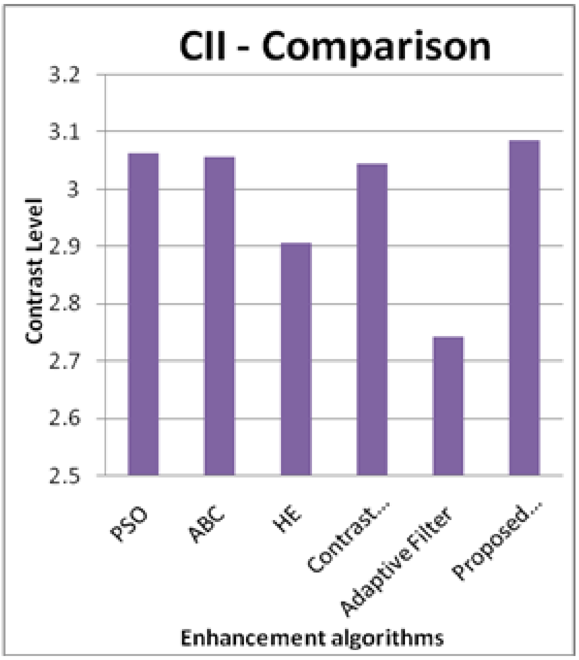

Figure 9. **Comparison with CII**

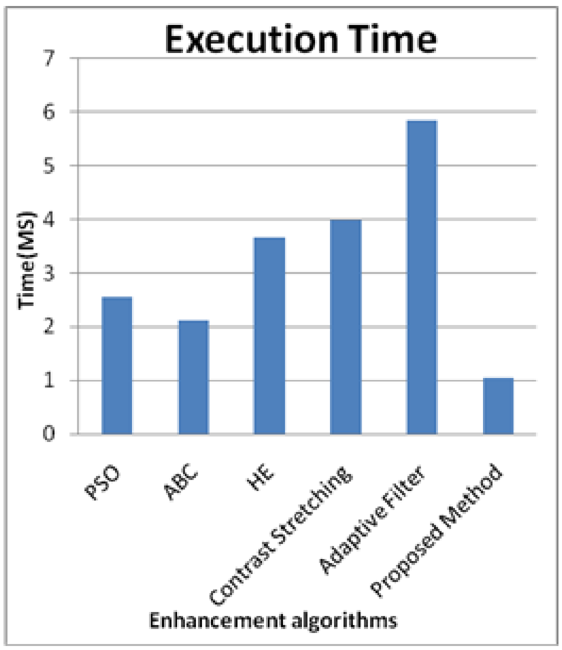

Figure 10. **Comparison with Execution Time**

From the enhancement algorithm results, the HPSO has better accuracy and structure similarity; improved contrast level with less peak signal noise ratio compared to other algorithms.

5 CONCLUSION AND FUTURE WORK

THIS paper proposed a new algorithm called Hybrid particle swarm optimization to enhance CT images which combine PSO and APSO. At the nutshell, the noise in the images is removed using median filter algorithm and the images are segmented using the watershed algorithm. Then the segmented image is enhanced in terms of luminance, contrast, brightness.

The performance of proposed algorithm is compared with the well known existing algorithms like Particle Swarm Optimization, Artificial Bee Colony, Histogram Equalization and the result shows that the proposed algorithm achieves better performance. The HPSO improves the accuracy of given CT images in terms of maintaining the structure similarity by 98.7%, improving contrast level 96.9% and the peak signal to noise ratio improved by 94%. In future HPSO can be applied to enhance the other modality images like MRI and Ultrasound.

6 DISCLOSURE STATEMENT

NO potential conflict of interest was reported by the authors.

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8 NOTES ON CONTRIBUTORS

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