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Sharpening Enhancement of Ultra Sound Images using Firefly Algorithm

Gurpreet Kaur
Dept. of Computer science and engineering,
Chandigarh Engineering college,
Gharuan, Mohali, Punjab, India

Rajdavinder Singh
Dept. of Computer science and Engineering,
Chandigarh Engineering college,
Gharuan, Mohali, Punjab, India

Abstract - Nature-inspired search algorithms have proved to be successful in solving real-world optimization problems. Firefly algorithm is a novel meta-heuristic algorithm which simulates the natural behavior of fireflies. This paper proposes a new sharpening technique based on the contourlet transform and firefly algorithm. Numerical results indicate the efficiency of the proposed approach. The parameters like enhancement measure (EME), structural similarity (SSIM), Echo Planar Imaging (EPI), and peak signal to noise ratio (PSNR) evaluate the improved performances of the proposed technique. The comparison shows that the proposed algorithm performs better in terms of the visual quality of the image and prove that artificial intelligence schemes based sharpening enhancement achieved better results than that of Contourlet transform technique.

Keywords - Medical ultrasound; Contourlet Transform (CT); Laplacian Pyramid (LP); Directional Filter Bank (DFB); Firefly algorithm; Metaheuristics.

I. INTRODUCTION

Medical images are very helpful to assist the anatomy of human body, to diagnose diseases and to interpret various problems in medical field. The most common and best technique for organ and soft tissue imaging are the ultra sound images. It is mostly used because of its portability, adaptability, non-surgical and does not have ionizing radiations. The unclear regions of the ultra sound images are enhanced for better visual quality [1]. Medical image enhancement technologies are getting much attention as new medical instruments are put into use in the medical field. Medical image qualities are usually contaminated by noise and other illumination conditions etc. In medical image enhancement, one mainly focuses on the poor contrast and higher level noise of the medical image.

In image enhancement problem, formulation is as follows: original low quality image (input image) and resultant high quality image (output image) for particular applications. Image enhancement is very active topic in medical imaging nowadays. The main objective of image enhancement is the visual quality of the image or to make a better representation for image processing, such as analysis, detection, segmentation and recognition [3]. The key step in detecting and analyzing medical image is the selection of image enhancement techniques which highlights the clarity of images for better human vision, removes blurring effect and noise, increases the contrast and highlights the important details are few illustrations for enhancement techniques. Every enhancement technique is different from other and it works out according to their objective. Basically, image enhancement has two techniques: Spatial domain and Frequency domain enhancement.

Image sharpening is basically the process which improves the intensity and the edge of the images to achieve the desired image [11]. This is the step which increases the details of the image as well as the sharpness of the image. Image enhancement is useful for taking the individual location into consideration as per scope of the research. The algorithm for sharpening is based on the information of color, coloring differences between different neighboring pixels and geometric areas of image that are taken into account. Basically, image sharpening is performed to highlight the important details or the enhancement of unclear details. Sharpening enhancement is the method for increasing the sharpness of the bright and dark regions to highlight boundary features [1]. Image enhancement is able to make differences in object by using its various techniques and to restore an image that was deteriorated while converting it from one form to other.

As there are many meta-heuristic algorithms, but the Firefly approach is one of the well-known branch based on the social behavior of fireflies and the process of bioluminescent communication. There are two important issues in the firefly algorithm: firstly, the change in light intensity and the attraction. Yang explained that the attractiveness depend on the brightness which is further concerned with objective function. The attractiveness is directly proportional to the brightness so the brightness decreases with the increase in distance. In this approach, every firefly is characterized by the bright that is expressed as an inverse of an objective function for the problem.

Traditionally, optimization techniques can be divided into two types: direct and gradient-based methods. Direct search methods are based on the objective function and constraint value which is used to guide the search whereas gradient based methods uses the 1st or 2nd order derivative of the objective function (OF) and /or constraints for guiding the search process. Direct search methods are slow and require many function evaluations for convergence whereas gradient

based methods converges to an optimal solution, having less efficiency in non-differentiable or discontinuous problems. So gradient search is also difficult and unstable because the objective functions have number of peaks. The limitations of these existing numerical methods forced researchers to use on the meta-heuristic algorithms to resolve the engineering optimization problems. Meta-heuristic algorithms are not restricted to particle swarm optimization (PSO), evolutionary computation (EC) including genet ic algorithms (GAS), and simulated annealing (SA) [4].

II. MATERIALS AND METHODS

Enhancement of sharpening the edges may result in more pleasant appearance of an image. Enhancing the sharpness by emphasizing the edges may thus contribute to a more pleasing appearance of an image. The degree of low sharpness around the object borders is formulated as slowly varying intensities in the spatial domain and low distribution or missing HF components in the frequency domain. Thus, obtaining effective HF components and add to the original certainly helps the sharpening algorithm and Firefly is used to find the optimized pixels for sharpening enhancement of image. Image enhancement is the essential technique in areas of image research. The primary objective of image enhancement is to enhance the visibility of an image, or to make it representable for further image processing tasks. Images are of various types like medical images, satellite imaging, and even real life pictures get affected from noise and poor contrast. So this is very important for the images to be enhanced for increasing the image quality by reducing its noise or on applying image enhancement techniques.

2.1 CONTOURLET TRANSFORM

Wavelet transform of an image is related with the gradient of the image and gives a natural mathematical framework for analyzing the edges. Although, the wavelet transform show the edges effectively, however they are not able to capture the contours because of its fixed size of basic functions i.e. isotropic property [1]. For capturing the smooth contours, Contourlet transform has elongated basis functions with different aspect ratios. The Contourlet transform has the multi-scale, multi-directionality decomposition method for an image. It is the rapid implementation having Laplacian pyramidal decomposition associated with the directional Filter banks which is processed on every band pass sub band. The contourlet transform also has the double iterated filter bank [2].

The contourlet is the double filter bank structure which can deal with piecewise smooth images with smooth contours and resultant image consists of contour segments, called contours and has the characteristics like multiple scales, directions and aspect ratio which can provide a smooth contour at multiple resolutions. The contourlet transform works on the assumptions that the Laplacian pyramid (LP) is used for detection of point discontinuity of an image and then the Directional filter bank is applied for linking that point discontinuities to the linked structures. DFB is a 2-d directional filter bank which can get perfect reconstruction. DFB implementation uses l-level binary tree decomposition and leads to 2^l directional sub bands with wedge shaped frequency partitioning.

2.2 FIREFLY ALGORITHM

Meta heuristic approaches are being commonly used in engineering optimization problems which include Genetic algorithms, particle swarm optimization, ant colony optimization, biogeography based optimization, etc. The best thing about meta-heuristic approaches is that they can handle both discrete and continuous variables, need not any gradients of objective functions and that is why, meta-heuristics approaches are gaining popularity day by day. Metaheuristic algorithms has become an essential part of global optimization algorithms and computational intelligence. These algorithms are inspired by nature having many interacting agents [5]. Meta-heuristics have a subset which is known as Swarm intelligence based algorithms and are developed from mimicking the swarm intelligence characteristics of biological species like birds, fireflies, humans etc. For example, firefly algorithm is inspired by the flashing pattern of fireflies and particle swarm optimization is based on the swarm intelligent behavior of birds and fishes.

The firefly algorithm is a population based algorithm to find the optimal solution of objective function based on the firefly's behavior. In this algorithm, physical entities (agents or fireflies) are spread in the search space arbitrarily. The Agents are thought of as fireflies that carry a luminescence quality, called Lucifer in, that emit light proportional to this value. Each firefly is attracted by the brighter glow of other neighboring fireflies. With the increase in distance, attractiveness decreases gradually. In the case no brighter firefly is present than a particular firefly, it starts moving randomly. Based on this objective function, initially, all the agents (fireflies) are randomly dispersed across the search space. The two phases of the firefly algorithm are as follows. [4]The firefly algorithm is a metaheuristic algorithm, which is inspired by the flashing behavior used by fireflies to attract each other in the mating process. It has been first proposed Yang in 2007 [8]. The brightness of the firefly is the key point of the algorithm, and is equivalent to the objective function under consideration. Three main assumptions were made when proposing the algorithm:

i) All fireflies are unisexual that is one firefly will be attracted by all others.

ii) Attraction is dependent on the amount of brightness that is a less bright firefly is attracted to a brighter one.

iii) The brightness of the firefly is equivalent to the objective function.

The attractiveness is dependent on the distance between the two fireflies as the intensity of light decreases as the distance between the two firefly's increases. Therefore, the closer the fireflies the more attractive they seem to each other. Multiple variants of firefly algorithm are being developed. The firefly algorithm has been proved to be efficient at solving optimization tasks and can be more efficient than other meta-heuristic algorithms when applied to continuous constrained optimization tasks, stochastic functions, multi-modal functions and even in the field of digital image

processing. Given the wide range of applications, less complexity and more efficiency than other meta-heuristic make the firefly algorithm a good subject for research.

2.3 PROPOSED METHOD

As we know that diagnosis of the disease is a crucial problem in the medical field. Nowadays the results of the medical tests like MRI, CT scan, ultra sound etc are in the form of digital pictures. Due to the advantageous characteristics of the contourlet transform, numerous research works has been made to know about efficiency in various image analysis and processing applications. Applications are denoising, image enhancement, texture classification, as well as more specialized image processing tasks like medical image analysis. Contourlet transform is a multidirectional and multiscale transform made from Laplacian pyramid and followed by directional filter bank (DFB). The Laplacian pyramid provides multiple resolution composition and DFB provides directional decomposition. The sharpening enhancement is defined as the increasing slope of intensities or in the frequency domain as intensification of higher frequency components. Sharpening can only enhance the details that are actually present in the image and defined by

$f^{\wedge}(U, v) = \{ f(u, v) + \alpha\, y(u, v);$

minimum $(\sigma) \geq \sigma_f$

$\beta\, f_j(U, v);\ \sigma_f < k$

$F(u, v)$; otherwise

$$Y(u, v) = \sum_{a=1}^{N} \{ \sum_{\theta=1}^{\theta} \gamma_{a,\theta} \mid S_{a,}^{D}\theta\,(u, v) \mid^2 \}$$

Where f(u,v) is the image to be enhanced, α is the parameter for determining the fraction of y(u,v) which is added with original for sharpening process. σ and σ_f are the local standard deviations of oriented response images. In this paper, the first thing to carry out is the image decomposition. An ultra sound image is taken on which Contourlet transform is applied for its decomposition by following Laplacian pyramid and Directional filter bank and firefly algorithm is applied for optimization. When Contourlet transform is applied, noise is also getting removed but the image quality was still low. So there is further requirement for enhancement in an ultra sound image for improving its visual appearance. The firefly algorithm based on artificial intelligence scheme is applied for sharpening enhancement. The firefly algorithm has two assumptions on which its whole working is based that are attraction and brightness. This algorithm uses randomization and local search. Firefly approach will call objective function and will initialize parameters for firefly population.

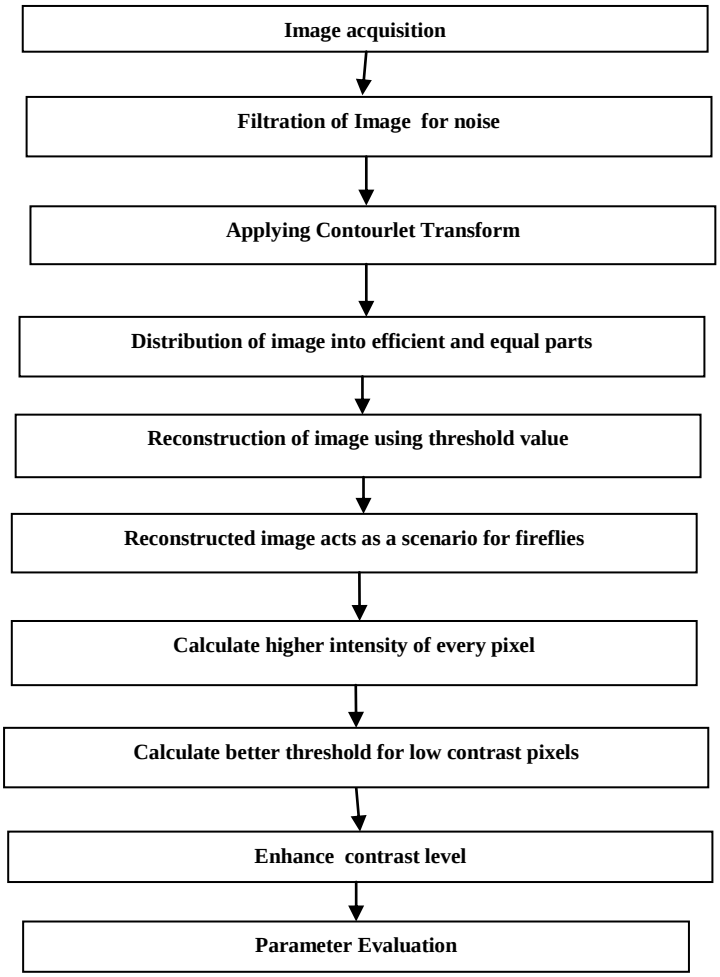

Fig1. Block diagram of proposed approach

In our proposed approach, filtration of image is performed to remove noise by using median filter. Contourlet transform is applied for wavelet decomposition and image is distributed into efficient and equal parts for further processing. Intensity value is obtained from each pixel and image is reconstructed by using threshold value. This Firefly approach will calculate higher intensity of every pixel and better threshold for low contrast pixels is also evaluated. Finally, the contrast level is enhanced and parameters are evaluated to demonstrate the performance. In this approach, intensity of firefly will be equivalent to the intensity of image and intensity value of the firefly is replaced or increased according to the distance value of the pixel and then all the pixels are combined to reconstruct the image. The image consists of pixels and every pixel has its own intensity and distance is calculated with the other neighbouring pixels. The use of multiscale edge information by this proposed firefly based sharpening method provides the noise suppression.

III. EXPERIMENTAL RESULTS AND DISCUSSION

This section presents the experimental results for proposed sharpening technique for ultra sound image enhancement. The algorithm is tested and analyzed both qualitatively and subjectively on ultra sound images dataset.

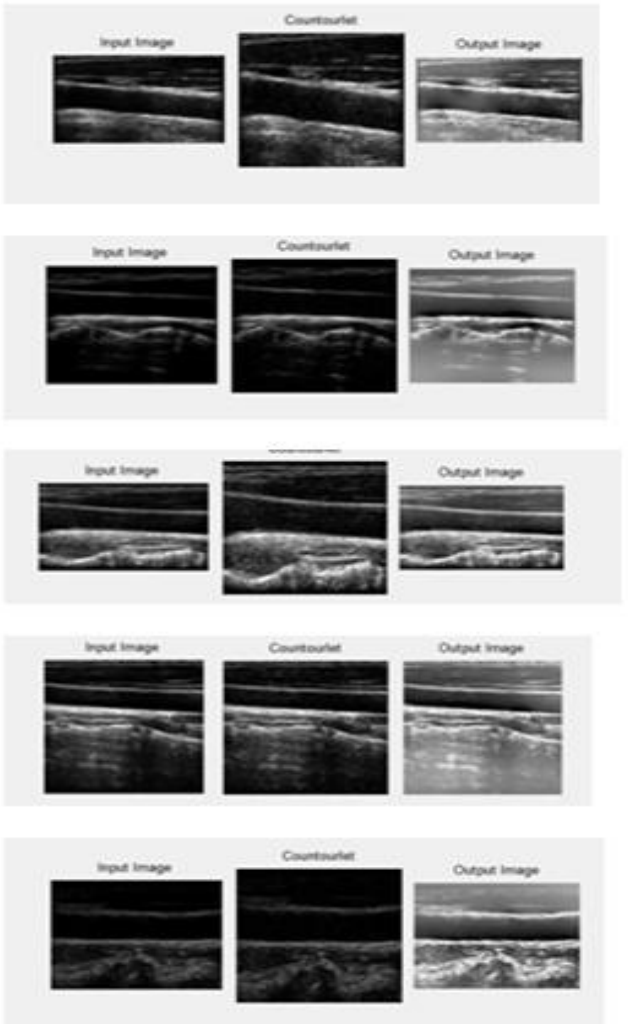

Fig2. Sharpening Enhancement Results: first column: original image; second column: contourlet transform; third column: Proposed method.

Table 1: Performance comparison of enhancement techniques using PSNR

Sample Images	Original	Contourlet	Proposed
Image 1	∞	10.1436	13.3817
Image 2	∞	10.4462	12.7185
Image 3	∞	11.2201	13.3107
Image 4	∞	11.4613	12.7617
Image 5	∞	10.0402	12.0483

Table 2: Performance comparison of enhancement techniques using SSIM

Sample Images	Original	Contourlet	Proposed
Image 1	0.741379	0.886138	0.999924
Image 2	0.841756	0.944507	0.999946
Image 3	0.741719	0.898495	0.999974
Image 4	0.668404	0.852853	0.999983
Image 5	0.628591	0.837484	0.999936

Table 3: Performance comparison of enhancement techniques using EME

Sample Images	Original	Contourlet	Proposed
Image 1	5.499882	6.701229	16.1835
Image 2	5.387596	6.350948	17.0603
Image 3	8.451542	10.109930	10.5958
Image 4	6.568308	7.400431	12.7646
Image 5	6.009416	7.170497	17.2678

Table 4: Performance comparison of enhancement techniques using EPI

Sample Images	Original	Contourlet	Proposed
Image 1	1.40126	1.45365	1.51516
Image 2	1.20135	1.30496	1.50491
Image 3	1.20149	1.99046	2.03003
Image 4	1.36462	1.50132	1.74405
Image 5	1.28413	1.56138	1.67728

This paper used a wavelet filter called Laplacian pyramid and DFB filters. The multi-scale and multi-directional values are assimilated which correlate and product the inter-scale edge information for performing sharpening enhancement on ultra sound images. For optimization, firefly algorithm is used to find out the best values of the image and then sharpening enhancement is performed to enhance the image. The proposed algorithm has a number of parameters and performance of the proposed algorithm is affected by the parameters. The comparison between the existing approach and the proposed approach is clearly demonstrating the betterment of the proposed approach to find the optimal solution. Therefore, solutions given by our approach is representing a good contribution for resolving the optimization problems to find the optimum solutions.

The proposed enhancement results are compared with the contourlet transform and the proposed method is sharpening the ultra sound image in much better way than the other method. The proposed technique gives the better performance than the contourlet transform technique in both subjective and objective measures for sharpening enhancement. The proposed methodology is giving the promising enhancement results shown in the tables above. The parameters evaluated for the comparison of performance are peak –signal-to-noise ratio(PSNR), structural similarity index (SSIM) , enhancement measure (EME**)** and echo planar imaging(EPI). PSNR is the ratio between the input and the output power of a signal and is expressed in decibels. It is an approximate value for human perception for reconstruction quality. SSIM describes the similarity of the structural information of an image. It is the quantitative and qualitative measure which accesses the perceived image quality. The index may be in between -1 to 1 and higher value of SSIM indicates that the image is not much destroyed from the original one while enhancement. EME is related with the level of enhancement. The proposed methodology achieved the higher value of EME as compared to other techniques. EPI is the

echo planar imaging also related to image quality. The significant aspects of visual appearance of an image are considered by three parameters: edge sharpness level, optimized values and the structural noise level. PSNR, SSIM, EME and EPI are tabulated in tables 1-4 and it is examined that the proposed sharpening technique is able to provide better visual appearance than the other conventional method, our method also highlights the hidden specific details.

IV. CONCLUSION

Firefly algorithm is the meta-heuristic approach that has luminescence quality which is carried by fireflies and based on attraction and brightness characteristics. In this paper, new algorithm is proposed based on the firefly algorithm and the contourlet transform for sharpening of ultra sound images. The contourlet transform does the multiscale and multi-directional splitting of an image and Laplacian pyramid and a Directional Filter Bank (DFB) are combined. To improve the results of contourlet transform, a new approach based on firefly is implemented and it is providing very high percentage of image quality for ultra sound images. In this work, firefly approach is used for the sharpening enhancement of the ultra sound images. The results demonstrates the improvement in the quality of the ultra sound images to find the optimal solution and parameters are calculated which shows that the proposed approach is performing better than the existing solutions. Comparison is done using sample ultra sound images between the contourlet transform and the proposed approach. For future, the proposed method can be used for other type of medical images as it is tested on ultra sound images only.

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