Bat algorithm based Softcomputing Approach to Perceive Hairline Bone Fracture in Medical X-ray Images

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Abstract—**Detection of bone fracture is easy if it is an open fracture and we do not need any special mechanism to identify that. But in case of closed fracture that is, hairline bone fracture the case becomes complicated. It is not always possible to detect that through bare eye. This is also a challenge for computer vision, through which detection of such cases could become easy and time saving. There are already a lot of methods and techniques available to solve this problem. But there is no such effort in the trend of using nature inspired metaheuristic algorithms. These emerging algorithms are becoming popular and can become a significant tool for computer vision. In this study, detection of hairline bone fracture is taken as a problem to be solved via implementing Bat algorithm. In the preprocessing stage this algorithm is been applied, to enhance the image, after which self organizing map (SOM) is used to draw segmentation and at last K-means clustering is used to produce the objective image. The results are exceptionally encouraging and the effectiveness of Bat algorithm as an image enhancer is proved.**

Keywords-medical imaging, hairline bone fracture, image processing, Bat algorithm, gamma correction, Self Organizing Maps, Kmeans, Peak Signal to Noise Ratio, histogram

I. INTRODUCTION

The main part of human skeleton is bone. With 206 named bones it is a multi functional part of human anatomy, it not only supports to carry body weight but it also help to protect vital organs and major blood vessels, storage of calcium, haematopoiesis production, permit movements etc. like any other part of human body, bones are also tends to damage, which is known as fracture. Fracture of bones may break a bone in more than one part which is also known as open fracture or a hairline fracture which is just a crack in the outer bone surface, known as closed fracture [1]. Medical imaging which involves computing technologies to be implemented to give a better prospective for medical practitioners to diagnose medical problems with the help of auxiliary support to catalyst the process of treatments. Involvement of X-ray (Wilhelm Roentgen, 1895) images in medical, especially on human bones is a several decades old technology. It is a electromagnetic radiation for which the wavelength ranges between 10 to 0.01 nanometers. Due to very short wavelength compared with visible light, it can penetrate deep and apart from that absorption of X-ray(s) in dense matter is less. Medical X-rays varies from problem to problem that means there is X-radiography, mammography, CT (Computer Tomography), these are various health condition based tests. Though X-ray produces good results in bone fractures but soft tissue injury cannot be properly detected by this technology [13]. Medical practitioners generally analyze the X-ray manually to deduce the condition to identify the severity of bone fracture [2]. Now a day's X-ray data are digitized and interpreted on computers. Open fractures are easy and fast to identify where as identifying closed fractures or hairline fractures takes longer time. If not treated properly with hairline fractures the chances for compound fractures in long run is high. The need of a proper decision support system to help practitioners will definitely save time which in turn will increase the number of patents to be treated. Through emerging technologies their always remains the chance for introducing better systems for interpretation of human health condition analysis. Grey level co-occurrence matrixes or GLCM which was proposed by Haralick (1979), to analyze image texture, has been used to identify femur bone fractures with a claimed rate of 86.67% success [3]. Involvement of soft computing classification techniques such as Support Vector Machines(SVM), Neural Networks(NN), Naïve Bayes Classifiers, fuzzy are well established [4][5][6]. Fracture classification compared with non-fracture images using SVM, Back Propagation Neural Network (BPNN) and Naïve Bayes, with texture feature, it was shown that SVM is better among them [7]. Segmentation is a way of identifying a group of objects based on a feature set. An ultrasound based 3-D bone fracture detection implements [8] local phase based feature extraction based segmentation, which provides a 3-dimentional view of the fractured surface. However the method needs to be tested in a real time clinical approach. Based on Bayesian's algorithm an image reconstruction approach [9] shows resulting image with better clarity and less ambiguity. The Bayesian analysis [10] which is

$p(x,y)=p(y/x)p(x)$ taken to $p(x/d)=p(d/x)p(x)/p(d)$ to calculate p(x) which nothing but probability density function and it is prior. A developing system known as FRACAS (Fracture Computer-Aided Surgery) which is a computer-integrated orthopedic system (Joskowicz et al.) to be used to help surgeons and reduce exposure to radiation, to overall uncomplicated the process of alignment and positioning errors of bone and tissues. However, it requires a preoperative CT study, some additional equipment, and a separate procedure for C-arm calibration. [11]. Fracture analysis based on CT images using Multiplanar and Maximum Intensity Projection Reconstructions [12] shows diagnosis of fractures in medial and anterior fossa with improved CT scan reading. However the system fails to detect hairline fractures. A study to show C-scan image to the image produced by the B-scan system, using C-scan image system the hairline fracture on the bone appeared as a bright strip [13]. But the integrated signal show more speckles and peak signal is low in contrast. Though, the system claims to detect fracture of range 0.5mm. A statistical graph based Hairline mandibular fracture detection from CT images, an intensity-based image retrieval approach with Kolmogorov-Smirnov (KS) distance algorithm in conjunction with Ford-Fulkerson algorithm had been employed next to obtain a minimum cut [14]. KS distance formula KS (Xc(x), Y c(x)) = sup x |Xc(x) − Y c(x)| had been used to intersect two cdfs (cumulative distribution functions) derived from pdfs, where X(x) and Y (x) shows distribution. Behind all this approaches discussed the common goal was to classify X-ray images to achieve the desired objective based on features. In general it was found that SVM and Bayes classification techniques, this fact is evident by a survey [15] reporting that suitability of a classifier for X-ray images was always compromised and moreover general classifiers those were used in satellite or natural scene classification were used more often. In this paper a nature inspired bat algorithm is employed for enhancement purpose, as a pre-processing step. After that SOM (Self Organizing Map) is generated upon which Kmeans clustering approach is applied to generate final outcome.

II. METHODOLOGY

A. Application of Bat Algorithm as an enhancer

Based on the echolocation behavior of microbats the Bat Algorithm has built on which in complete darkness they can find their prey. The algorithm was proposed by Xin-She Yang [16] in the year of 2010. Based on the echolocation they also avoid an obstacle, which is an important characteristic when flying in the dark, the frequency return for which is different. There are some assumptions that the algorithm takes, those are:

1) All bats use echolocation to sense distance, and they are also 'aware' of the difference between food/prey and background barriers in some magical way;
2) Bats fly randomly with a fixed frequency of varying wavelength and loudness to search for prey. They can automatically adjust the wavelength of their emitted pulses and adjust the rate of pulse emission depending on the proximity of their target.
3) Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) to a minimum constant value.

The original [16] bat algorithm is shown below:

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Objective function f(x), x = (x1, ..., xd)T
Initialize the bat population xi (i = 1, 2, ..., n) and vi
Define pulse frequency fi at xi
Initialize pulse rates ri and the loudness Ai
while (t <Max number of iterations)
        Generate new solutions by adjusting frequency,    and updating velocities and locations/solutions
        [equations (2) to (4)]
        if (rand > ri)
        Select a solution among the best solutions
        Generate a local solution around the selected best    solution
end if
        Generate a new solution by flying randomly
        if (rand < Ai & f(xi) < f(x*))
        Accept the new solutions
        Increase ri and reduce Ai
end if
        Rank the bats and find the current best x_
end while
        Postprocess results and visualization
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To implement it as an image enhancer and cater it to the needs of the problem a few assumptions are made.

1) Difference of food and background are taken as a difference of pixel values of same cluster.

2) Random fly of bats, implemented as the random distribution search of a threshold value in terms of pixel variations. Automatic adjustment of the threshold values have been calculated in terms of local search of the expected high pixel values.
3) Loudness has been identified as an important parameter which helps to give the smoothing effect on images. It has been considered as a value of a variable named gamma and implemented as the last stage of enhancement to distribute the highest found pixel value evenly throughout the image.

The provided pseudo algorithm in the original paper has been implemented in terms of the derived assumptions. All the experiments have been implemented and realized using MATLAB as tool. Results of enhancement are satisfying and pre processed image was further processed to produce desired outcome. Figure1 shows the original image where as Figure2 shows the semi enhanced image after applying Bat algorithm.Figure3 shows the final enhanced image after implementing Gamma correction as discussed in derived assumption number three.

Figure 1: original image

Figure 2: Semi enhanced image

B. Application of gamma correction

Gamma correction [17] [18] [19] [20] [21] always considers enhancement of image contrast. In a video system, linear-light intensity is transformed to a nonlinear video signal by gamma corrections. The numerical value of the exponent of power function is known as gamma. Application of gamma correction can be found in medical images, remote sensing images etc. Here in this approach the loudness was considered to be gamma and further gamma correction has been applied. The gamma correction here considered as being a part of bat algorithm based image enhancement.

Figure 3: after gamma correction

C. Application of SOM

Self-Organizing Map (SOM) Neural Network is a kind of unsupervised artificial neural network. SOM help us in segmenting the regions of the image that has similar features [22] [23] [24], it makes more compact segments.

In SOM each neuron has a weight vector associated with it. SOM generally do not degrade the image quality as much. Topology of an image accounts to be an important factor, topology of the SOM map becomes more significant as the size of the SOM is increased. With larger SOMs, the measure becomes less informative as the number of images sharing a BMU becomes overly small and the perplexity value mostly reflects just the size of the image class. Random initialization has been chosen for this approach with a size of 8x8. Best Matching Unit (BMU), which depends upon the lowest non-similar values of the image take care of the initial SOM. Weight associated with each neuron was updated according to the found new values after fixed value iteration. Before achieving maximum iteration, all pixels of an image has been represented in SOM. Training of SOM was conducted at 25 epochs, with best found learning rate found to be 0.7.

Figure 4: After SOM

D. Application of K-means

In K-means clustering a centroid vector is computed for every cluster. [25][26] In K-means algorithm data vectors are grouped into predefined number of clusters. Using Euclidian distance measure rule, each pixel is assigned a cluster. After SOM the image was processed by k-means, which a partition map has been created. New centroids have been calculated to be induced within the cluster pixels. Membership of present clustered pixels renewed based on new found centroids. Iteration has been conducted upto the level of convergence. With different initial conditions, the K-means algorithm may result in different partitions for a given data set and there cannot be any best found clusters. Though a common cluster validity criterion is the ratio of the total between-cluster to the total within-cluster distances

Between-cluster distance (BCD), which is the distance between means of two clusters.

Figure 5: after K-means

III. RESULTS

The result of the methodology proposed here found to be very encouraging in terms of both visually and quantitatively. Bat algorithm, in the preprocessing stage improved the quality of the image significantly. The calculated PSNR was around 40.5, which indicates the improvement in image quality. Applying SOM as an unsupervised learning tool produced the desired outcome which was used further in K-means. The SOM map generated a near to be perfect segmentation that amplifies the region of interest, as it was the hairline fracture zone. Application of k-means results into optimal final stage of detection.

IV. CONCLUSION

The procedure discussed here produces results with far more clarity as needed. The nature inspired bat algorithm based image enhancement was found to be very effective. This preprocessing stage was significant as further all other procedures depends upon it. SOM and k-means in conjunction helped to identify the hairline fracture in bone. There are lots of other nature inspired metaheuristic algorithms are present, those need to be tested in accordance with the problem definition discussed here.

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