Volume 8, No. 4, May 2017 (Special Issue)
ISSN No. 0976-5697
International Journal of Advanced Research in Computer Science
REVIEW ARTICLE
Available Online at www.ijarcs.info

A Study of Particle Swarm Optimization based K-means Clustering for Detection of Dental Caries in Dental X-ray Images

[#1]Er. Jagdeep Kaur
Research Scholar
Computer Science Engineering
Desh Bhagat University
Mandigobindgarh, Punjab (India)
jagdeepkaurrai859@gmail.com

[#2] Prof. (Dr.) Jatinder Singh Bal
Professor & Vice-Chancellor
Computer Science Engineering
Sant Baba Bhag Singh University
Padhiana, Jalandhar, Punjab, India
bal_jatinder@rediffmail.com

Abstract—Evolutionary computational techniques have been very helpful in solving Bio-medical related problems. These techniques work on the principle of Artificial Intelligence. In the current work we have evaluated swarm intelligence based clustering technique for diagnosis of Dental caries, a disease quite prevalent among all age groups. Training and Testing has been done using Neural network. Processing time and Percentage Level of accuracy has been computed.

Keywords—Particle Swarm Optimization (PSO), K-Means Clustering (K-Means), Swarm Intelligence, Image Clustering, Image Segmentation.

I. INTRODUCTION

1.1 Swarm Intelligence

Swarm intelligence (SI) [1] is artificial intelligence based on the collective behavior of decentralized, self-organized systems. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local interactions between such agents lead to the emergence of complex global behavior. Natural examples of SI include ant colonies, bird flocking animal herding, bacterial growth and fish schooling. Swarm Intelligence techniques include- Particle swarm optimization, Ant Code Optimization, Biogeography based optimization, Bee Colony Optimization, Stochastic Diffusion Search, Bacterial foraging optimization.

1.1.1. Particle Swarm Optimization

This paper concentrates on a population based optimization technique, a field of Swarm Intelligence, called Particle Swarm Optimization[1].

Particle Swarm Optimization[1] is modeled after the social behavior of flocks of birds. This algorithm is initialized with a population of random solutions, called particles. Each particle flies through the searching space with a velocity that is dynamically adjusted. These dynamical adjustments are based on the historical behaviors of itself and other particles in the population.

$xi = (xi1, xi2, \dots \dots \dots xiD)$

represents the ith particle, the best solution is

$pi = (pi1, pi2, \dots \dots .. piD)$ also called pbesti.

The best solution of all particles is pgg , also called gbest,

$Vi = (vi1, vi2, \dots \dots .. viD)$

is the velocity of particle i.

For every generation, the velocity changes according to the following equation:

$$vid = w * vid + c1 * rand1(\ ) * (pid - xid) + c2 * rand2(\ ) * (pgd - xid)$$

---*Equation-1*

$$xid = xid + vid$$

---*Equation-2*

Where d=1,2,…S, w is the inertia weight, it is a positive linear function of time changing according to generation iteration, often changing from 0.9 to 0.2. Suitable selection of inertia weight provides a balance between global and local exploration and results in fewer iterations. The acceleration constants, c1 and c2 represents the weighting positions. rand1 and rand2 are random functions which change between 0 and 1.

1.2 Data Mining

Data Mining [2] is an analytic process designed to explore large amounts of data in search of consistent patterns and/or

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systematic relationships between variables, and then to validate the findings by applying the detected patterns to new subsets of data. In order to achieve this, data mining uses computational techniques from statistics, machine learning and pattern recognition. This paper focuses on available data mining technique for unsupervised clustering of dental X-ray images.

1.2.1 Image Segmentation

Image segmentation refers of dividing an image into its constituent regions or objects that are homogeneous and in-homogeneous in some properties. Segmentation is helpful in image analysis and pattern recognition. The main goal of segmentation is to find the area of interest in an image [3, 4]. Image segmentation generally aims in better recognizing of the objects of interest, i.e., in finding suitable local features that can be distinguished from other objects and from the background of an image. Image segmentation is the first step in image analysis. Segmentation may also depend on the various features that are contained in the image.

Practical applications of image segmentation ranges from content-based image retrieval, medical imaging, and recognition tasks etc. The diversity in segmentation types led to the wide range of approaches for image segmentation [5, 6].

1.2.2 Clustering

Clustering [8] can be defined as the identification of natural groups within a multispectral data set. The algorithm that perform clustering functions to partition a set of objects (pixels) into relatively homogenous subsets based on inter-object similarities with little or no overlap.

In general, clustering methods can be categorized by principle (objective function, graph theoretical, hierarchical) or by model type (deterministic, statistical, heuristic, fuzzy). In the traditional clustering algorithm, the samples are classified in the unique cluster, which is all known as a hard division. However, there is not definite boundary in most things. The concept of fuzzy clustering applies to the essence of most things, and reflects the reality of objects better.

Clustering algorithms are usually applied to feature space, and as such they do not use any spatial information (e.g. the relative location of the patterns in the feature space).

One major limitation of many classical clustering algorithms is that they assume that the number of clusters is known. However, in practice, the number of clusters may not be known. This problem is sometimes called *unsupervised clustering*. Unsupervised prototype-based clustering aims at determining the correct number of clusters, C, without any prior knowledge about it.

1.2.3 *Imaging Modalities*

Many different imaging techniques have been developed and are in clinical use. Because they are based on different physical principles, these techniques can be more or less suited to a particular organ or pathology [8]. In medical imaging, these different imaging techniques are called modalities.

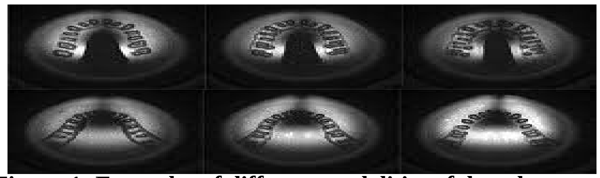

Figure-1: Examples of different modalities of dental structure

Anatomical modalities provide awareness into the structural morphology. They include radiography, CT and MRI. There are several derived modalities that sometimes appear under a different name, such as magnetic resonance angiography (MRA, from MRI), digital subtraction angiography (DSA, from X-rays), computed tomography angiography (CTA, from CT) etc [9, 10, 11].

Functional-modalities, can represent the actual metabolism of the primary organs or tissues. They comprise of the three modalities of nuclear medicine, specifically, scintigraphy [12, 13], single-photon emission-computed-tomography (SPECT) along with positron-emission-tomography (PET), in addition to functional magnetic-resonance-imagery (fMRI). This specific list is not comprehensive, as new-fangled methods are being added every few years as well. Practically all types of the images are now assimilated digitally and combined in a computerized-image archiving and communication-system (PACS).

1.2.4. K-Means clustering[2]

1. Place K points into the space represented by the objects that are being clustered.
2. These points represent initial group centroids.
3. Assign each object to the group that has the closest centroid.
4. When all objects have been assigned, recalculate the positions of the K centroids.
5. Repeat Steps 2 and 3 until the centroids no longer move. This produces a separation of the objects into groups from which the metric to be minimized can be calculated.

1.3 Dental Cavity[7]

Dental cavity and periodontal diseases are the most common dental diseases. If they are not treated in early stages, they may lead to progressive distraction of tooth and infection of the dental pulp.

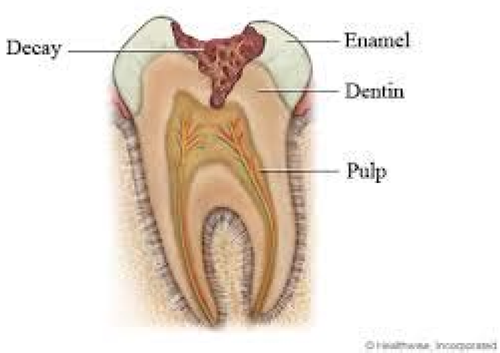

Figure- 2: Structure of tooth with decay(source-beautifulsmiles.org)

Classification of dental cavity is decided based on whether the lesion or decay is within the enamel, dentin or whether it touches the pulp [7]. Based to the extent of attack dental caries may be classified as- Enamel, Dentinal and Pulpal caries. In enamel the caries have affected the outer enamel portion alone and the inner dentine and pulp regions are healthy. In Dentinal, the lateral spread at the dentino-enamel junction occurs with involvement of underlying dentin. In Pulpal, the micro-organisms have spread to root surface and affected roots.

II. OBJECTIVES

The objective of this paper is to enhance the quality of the Dental X-ray image, for this we need to-

- To develop an efficient clustering algorithm based on PSO.
- To develop an efficient clustering algorithm that can find the “optimum” number of clusters in a data set
- To show that PSO can bring out results with in reduced iterations.
- To show that PSO is good at converging to global optima, then getting hooked up in local optima, as in case of traditional clustering techniques, thus explore a larger search area to get better and accurate results
- The main objective of using PSO is its easy understandability, with the use of simple mathematical calculations dealing with changing velocity and position.

III. PARTICLE SWARM OPTIMIZATION BASED K-MEANS CLUSTERING

The hybrid PSO/K-mean module consists of two modules, i.e. PSO and K-Mean Clustering. At first, PSO is executed for a short time, then the clusters are transferred to K-Mean algorithm to find the optimal solution.
In the PSO+K-means algorithm, the features of PSO section of global search and features of K-Mean of best searching would be utilized. The PSO algorithm will be used in the initial section to get global search. The result from PSO is used as the initial seed of the K-means algorithm, which is applied for refining and generating the final result.

3.1 Training and testing using PSO based K-Means[15]

The process of PSO K-Means clustering algorithm can be described as follows:

```
For training process; Load
K-Means features;

Initialize neural for training;

net.trainparam.epochs=50; Save
neuralK-Means; Training Done;

For testing process; Read
image= test image Upload
test sample Histogram
calculation; Cluster
initialization;
Calculate minimum distance to get
clusters;

Calculate closet cluster;
Calculate cluster count; Do
data mining;

Load neuralkmean; Features=
test features; Stop;
```

IV. SIMULATION ENVIRONMENT

The experiment is simulated in the MATLAB 2010a. Following are the results that have been achieved for optimizing the results.

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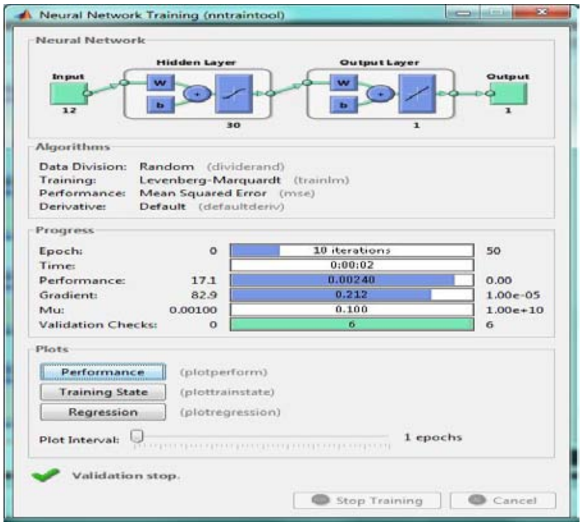

Figure-3: Training for K-Mean Technique

The above figure shows the training of K-Mean technique using neural network [14]. Above figure shows the training is done using various neural functions like no. of epochs = 50, no. of validations = 6.

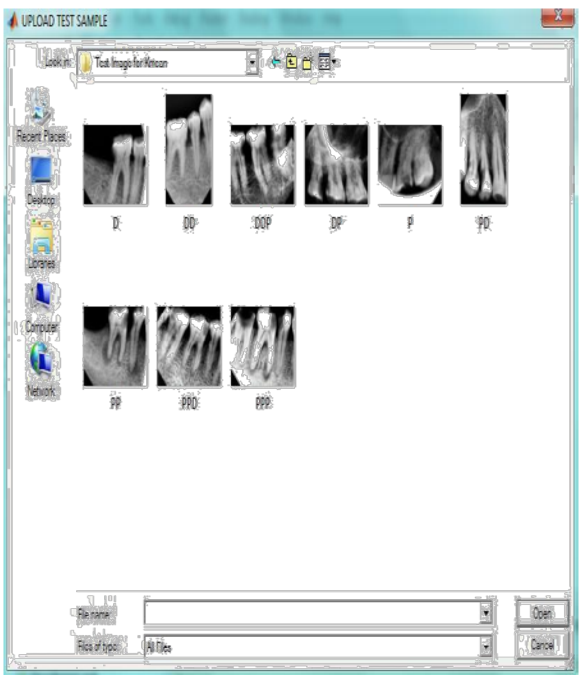

Figure -4 : Testing for K-Mean Technique

Above figure shows the uploading of dental images using k-Mean technique on which after training, testing will be done. For testing basically 9 dental images has been chosen. When training will be done then feature extraction will be done using PCA feature extraction method. During feature extraction various feature vectors will be obtained and in the end test image is obtained.

Figure- 5: Segmented Image[15]

Above figure shows the segmented image that has been achieved by using PCA feature extraction method. Above figure shows the after PCA application K-Mean algorithm utilization will be done in which only relevant part will be taken. PCA involves the calculation of the Eigen value decomposition of a data covariance medium or singular value decay of a data matrix, usually after mean centering the data for each attributes

Figure-6 : Classification Of Dental X-Ray image

Above figure shows the classification of dental image is done using training and testing. Firstly PSO based k-mean has been utilized for training and in second step on the basis of training, testing is done in which above test image has been found out to be one of " Dentin group.

Table-1 Accuracy table

Types	**PSO based K-means(%)**
Dentin	**92.4**
Dentin-Dentin	**93.2**
Dentin-Dentin-Pulpal	**94.5**
Dentin-Pulpal	**93.7**

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Pupal	**91.3**
Pulpal-Dentin	**92.5**
Pulpa-Pulpal	**93.5**
Pulpal-Pupal-Pulpal	**95.8**
Pulpal-Pulpal-Dentin	**95.4**

Accuracy table 1 shows PSO based K-Mean (%) and for different images like Dentin, Dentin-Dentin, Dentin-Dentine-Pulpal, Dentin-Pulpal, Pulpal, Pulpal-Dentin, Pulpal-Pulpal, Pulpal-Pulpal –Pulpal and Pulpal-Pulpal-Dentin. Accuracy table presented the values of segmentation rate in terms of percentage.

Processing Time for PSO based K-means is 40 seconds. Processing time is the time consumption value for segmentation utilized by K-Mean along with PSO clustering method.

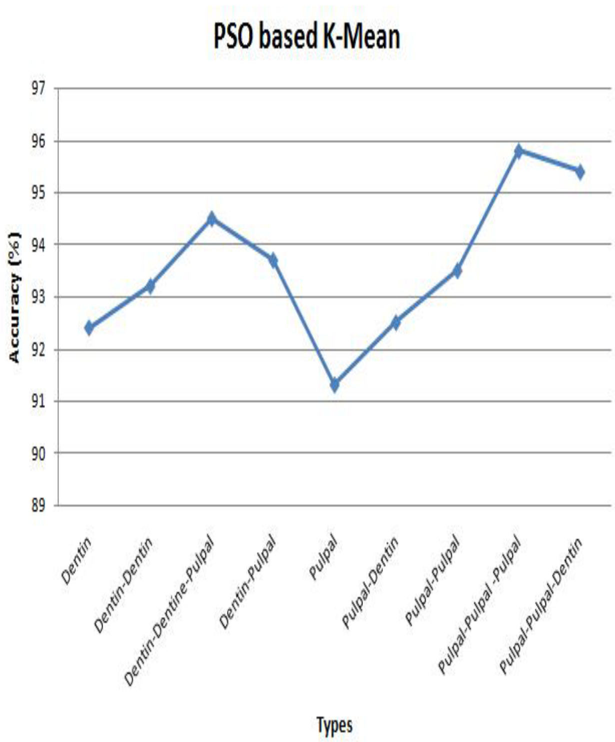

Figure- 7 : PSO Based K-Mean Results

For the number of dental images, the above figure shows the results with the use of K-Mean algorithm. The Dentin value for accuracy on the basis of K-mean came out to be 92.4, Dentin-Dentin to be 93.2, Dentin-Dentine-Pulpal has 94.5, Dentin-Pulpal gives 93.7, Pulpal has 91.3, Pulpal-Dentil has 92.5, Pulpal-Pulpal has 93.5, Pulpal-Pulpal –Pulpal gives 95.8 and Pulpal-Pulpal-Dentin gives 95.4 values. As k-Means algorithm works on the principle of selection of k of the objects. Each selected object represents a single cluster and because in this case only one object is in the cluster, this object represents the mean or center of the cluster and then clustering is done. The proposed work has shown better values.

V. CONCLUSION AND FUTURE SCOPE

The use of the conventional PSO algorithm for medical image analysis is widespread because of its advantages, such as always being able to produce a complete division of the image. However, its drawbacks include over-segmentation and sensitivity to false edges. So, this paper has made an attempt to compare the traditional methods.

In the recent future various parameters can be chosen to measure the performance of the proposed technique like accuracy rate, time complexity etc.

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