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Intelligent Identification of Dental Age Assessment using Elman Neural Network with Guaranteed Convergence Particle Swarm Optimization

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Abstract: Age is most important factor for every individual in their life. Dental Age (DA) estimation is used for criminal, civil, anthropologic and forensic purposes. Numerous techniques have been provided to evaluate chronological age for these applications. It includes somatic growth measurements which depend on the progress of tooth. Estimation of age has been consumed for long time by the incremental development of tooth. Therefore, DA is measured as substantial fact for establishing individuals' age. Here, an Elman Neural Network (ENN) with Guaranteed Convergence Particle Swarm Optimization (GCPSO) algorithm is proposed for dental age classification. Initially, OPG input tooth image is preprocessed using Anisotropic Diffusion filter (ADF) for smoothing the image and removal of noise. Teeth image has been segmented by kernel based Fuzzy C-means clustering with Dragonfly optimization then morphological post processing is utilized to enhance the image feature precision. Exact features are extracted and age is classified with ENN-GCPSO. Investigational results determines that ENN-GCPSO obtains better accuracy of 89%, specificity of 83.5%, precision of 72.15%, recall of 92.3% f-measure of 74.54% than the existing classifiers such as ENN-DO, MELM-SRC,RBFN and ANFIS schemes.

Keywords: Dental age, Elman Neural Network, Guaranteed Convergence Particle Swarm Optimization, Anisotropic Diffusion filter, kernel based Fuzzy C-means clustering.

1. INTRODUCTION

In Forensic Odontology, the Age is an important factor for evaluating the age credentials of people. Age estimation is mainly used for civil, criminal and forensic odontology. Also the age of unknown figures can be evaluated which assists a mark out exploration for the evidence by tapering the age provisional of the pursuit.

For detecting the age of subject can be identified using bone ossification, ethnicity but there is no exactness information for the age of subject. So teeth can be exploited for predicting their age.[1] Dental age (DA) which is most important indicator for gauging the age of an individual than the skeletal indicator. It is the most commonly used indicator in forensic for identifying the cadaver victims and also for crimes, pediatric endocrinology and clinical dentistry. [2] To estimate the chronological age of an individual, dental maturity plays a vital role. Estimation of an age can be viewed as age-related issues observed in teeth. Based on the changes occurred in the teeth to identify the more accurate CA that contributes for finding the

age in future. The tooth morphology or any progression of the tooth has considered as age related features.
There are various methods for setting up age which includes tooth morphology, Atlas method (i.e. Demirjian's strategies), and Cameriere's techniques, Mornstaad' techniques. [2][3] for estimating the age, teeth were partitioned in to two classes 1. Milk tooth and 2. Permanent tooth. [5] In the infantile age, the tooth eruption and the development of permanent tooth are an important factor for determining the age. Age can be estimated by the tooth developmental chart using radiographs. [6][7] Determining the age based on bone advancement is the most much of the time utilized technique.
Several methods are used for age assessment between youngsters by Nolla in 1960, [11] by Moorrees in 1963, [12] by Haavikko in 1970, [13] and by Demirjian in 1973. [6] Up on which the most common technique was used to identify the age of a subject based on the dental progression is Demirjian's technique. [14][6] in the above technique, the development of tooth is represented in eight phases from A to H and evaluation are done based on the left mandibular teeth which ignores the wisdom tooth. Due to the over estimation of age can be assessed than the CA, Willems et al. modernized the Demirjian's approach. [15]. although, in the investigations using Demirjian's approach is not entirely perfect in the locations such as Turkey, especially in locales that have hot atmospheres (i.e. Mediterranean district, Aegean area, and Middle Anatolia). [16][17] There is no modern tool to estimate the DA for the southern Indian population. In the present investigation were to measure the correctness and accuracy of Demirjian's technique for the southern Indian population to separate the feasibility of this approach in various age groups up to 18 years for the two genders by exploiting classification scheme of ENN-GCPSO and also compared their performance with the existing classifiers.
The outline of this paper has different stages are revealed as stage 2 deliberates related works of DA estimation. Stage 3 elucidates the proposed ENN-GCPSO based organization and the stage 4 assessed the implementation. Lastly, this work is concluded.

2. RELATED WORKS

Sehrawat and Singh (2017) [14] suggested a Willems method which is reviewed form of Demirjian method built on improved dental development marks to assess the age of progenies intended for the genders together[7]. The comparative assessment between chronological and estimated eternities of a distinct was minor range of age (-0.04 and -0.02 years) than the Demirjian method (around six months).

Bunyarit et al., (2017) [15] focused on age that has been estimated for the kids and juveniles of Malay Populace. The applicability of Demirjian's score can be depicted with the organization of left mandibular eternal teeth in Malay children aged between 5– 16 years. To progress a novel technique for estimating the dental age of Malay kids based on a variation of the dental development marks.

Kihara et al., (2017) [16], measured the accuracy of dental age was determined by Willems' method for the children aged between 3-16 years at UND hospital[8]. It was noted that the William's method was suitable for estimating the age of the girls than the boys. In Kenya, Willems' method is more appropriate for assessing the ages of individual children.

Kapoor et al., (2017) [17] proven that age was estimated for the Himachali children of 55 subjects using both Willem's dental age (DA) assessment methods and Mito T Skeletal Age assessment method. From these methods, William's method was more precise compared to the SA method for estimating the Chronological age of the Himachali children.

Machado et al., (2018) [18] observed that the three methods were used for estimating the age ranging from 5-15 years old. Three age assessment methods were 1) Dental development 2) Hand and wrist bone escalation 3) both above methods combined together for estimations. Up on which the methodologies include dental progression gave more precise results on identification of subject's age.

Rath et al., (2017) [19][4] shown the exploitation of Demirjian method was adopted in our East Indian population. There were 106 OPG of different age groups ranged from 7 – 23 years with both sexes were assessed for eight left mandibular teeth and scored as per the Demirjian's 9-stage standards for teeth progress phases. The lower error rate was predicted in estimating the age using Demirjian method. This can be adopted for different population of the world.

Fantasia et al., (2016) [20] gauged the comparative analysis of CA and DA by utilizing Nolla and Demirjian method from the age up to 18 years for both genders. In this, Demirjian method predicts overestimate CA for 6 months and Nolla method tend to underestimate it. So Nolla method was further substantial for especially girl kids up to 18 years than the Demirjian method.

Jagmahender Singh Sehrawat et al., (2016) [21] estimated the accuracy of Nolla's technique for assessing the dental age which was useful for the forensic purposes. OPG of healthy subjects of age ranged from 3 to 18 years and also found the mean difference between the DA and CA were comprised in the review for meta-analysis. He noted that Nolla's method of dental age estimation underrated the dental age than the chronological age of an individual.

Kumaresan et al., (2016) [22] gauged consistency and strength of Demirjian's, Willems, Nolla's, Haavikko's, and Cameriere's radiographic approaches of dental-age estimation in people of Malaysian progenies. There were 426 dental panoramic radiographs of Malaysian kids' ranges from 5-15-year old for assessing the dental age. In this, Cameriere scheme of dental-age estimation is highly effective and reliable for Malaysian people than Haavikko and Demirjian strategies chased by the Willems and Nolla methods.

Altan et al., (2016) [23] inspected the applicability of Willem's method were used for assessing the age of southern Turkish kids ranges from 5-15 years for both sexes. In this investigation, Willems' technique was more scrupulous for girl children than for Boys[9].
DA estimation is important reliable indicator for assessing the age of the subjects. In the above researches noted that the numerous dental progression approaches have been presented to conclude automatic DA estimation problem. The age accuracy is an important factor that has considered for future. Here, the organization is needed for the age precision on image processing steps by using ENN-GCPSO.

3. PROPOSED METHODOLOGY

This part deliberates in fact about predicted ENN- GCPSO based classification and estimation of dental age[10]. The steps such as pre-processing, segmentation, feature extraction and classification have been supported for improving exactness of age identification. The estimated prototype is well organized and assessed based on the above steps. Fig.1 shows the system architecture for dental age identification:

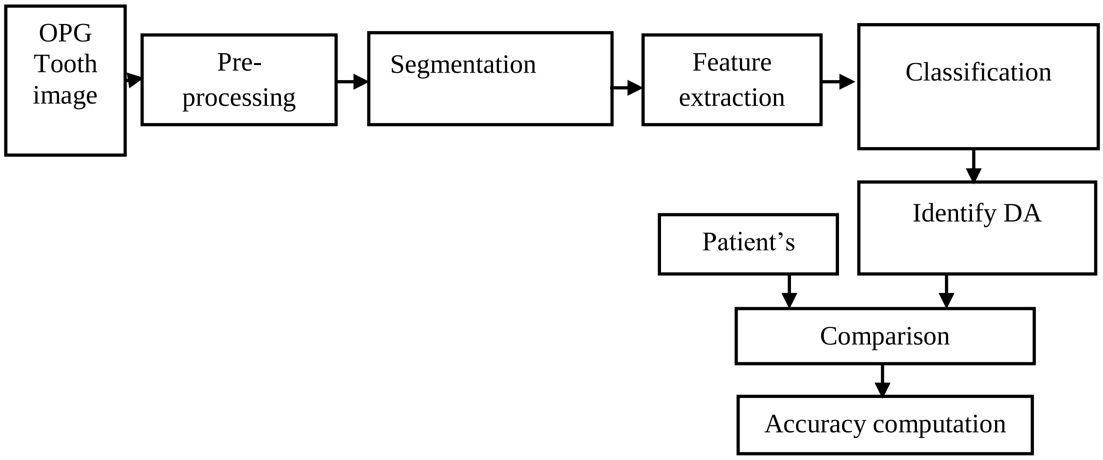


Fig.1: System Architecture for Dental Age Identification

3.1 Organization outline

The model presented here comprises of four phases such as image acquisition, pre-processing, segmentation, feature extraction and classification. Anticipated model is shown in Fig. 1.

Image acquisition: OPG Teeth image is collected from Kovai Scan Center, Coimbatore.

Pre-processing: The main aim of pre-processing is to augment image quality by decreasing the noise and smoothing the image without the loss of data using ADF.

Segmentation: After pre-processing, the smoothened image has been segmented using kernel based Fuzzy C-means clustering with Dragonfly optimization, followed by morphological post processing has been utilized for classification precision.

Feature Extraction: Ten features have been extracted for further classification.

Classification: The main aim is to identify the precise person with age which is useful for endocrinology disorder and also criminological. Here, ENN- GCPSO has been developed for finding the age of person and compared it with existing method as Demirjian Method.

3.2 Dataset Collection

OPG of teeth image dataset is collected from Kovai scan center, Coimbatore. About 100 healthy OPG images of south Indian Juveniles are utilized for calculating CA and DA[29].

3.3 Preprocessing

The main objective of preprocessing is to increase the image quality and to eradicate the noise in the given image. Here, Anisotropic Diffusion filter (ADF) has been utilized for enhancing the image quality and de-noising the image[30]. The main aim of ADF is to reducing the noise without removal of the edges in given image. The general form of ADF is as [24]

$$I_t = c(x,y,t)\Delta I + \nabla c \nabla I \qquad (1)$$

In this, I is the original image, ΔI, ∇I represents the gradient and the Laplacian of the image respectively and $c(x,y,t)$ is denoted as the diffusion constant

The equation (1) can be written as

The value of the diffusion constant $c\ (x, y, t)$has been calculated by:

$$c(x, y, t) = g(\nabla I) \qquad (2)$$

$g(\nabla I)$ is the conduction coefficient function and is represented by:

$$g\ (\nabla I\ ) = e^{(-(\|\nabla I\|/k)^2))} \qquad (3)$$

$$g\ (\nabla I\ ) = \frac{1}{1+\left(\frac{\|\nabla I\|}{k}\right)^2} \qquad (4)$$

3.4 Segmentation of Teeth using kernel based Fuzzy C-means clustering with Dragonfly Optimization:

The main goal of segmentation of teeth is to deliver an improved partitioned of whole teeth image boundaries using kernel based fuzzy C-means clustering. In this algorithm indicates that the whole teeth pixel regions are grouped in to one cluster and the out of these pixels are grouped into another cluster.

FCM is an unsupervised method which is not suitable for the large datasets. So kernel has been introduced using a Euclidean distance$\|x_i - \alpha_j\|$ [25]. This kernel function is incorporated into FCM aims to minimize the given objective function.

$$I_m(X, Y) = \sum_{p=1}^{c} \sum_{k=1}^{n} X_{pk}^m \|\emptyset(o_k) - \emptyset(v_p)\|^2 \qquad (5)$$

$\|\emptyset(o_k) - \emptyset(v_p)\|$ is the inner kernel product function.

The equation 5 can be minimized under the limitation of X_{pk}^m

$$X_{pk} = \frac{\left(1/_{(1-K(u_k, v_p))}\right)^{1/_{(m-1)}}}{\sum_{j=1}^{c}\left(1/_{(1-K(u_k, v_j))}\right)^{1/_{(m-1)}}} \qquad (6)$$

$$v_p = \frac{\sum_{k-1}^{n} X_{pk}^m K(u_k, v_p) o_k}{\sum_{k-1}^{n} X_{pk}^m K(u_k, v_p)} \qquad (7)$$

Based on the equation (7), the additional weights have been measured the similarity between u_k and v_p. When u_k is the misclassified cluster, i.e., if the u_k is far away from the other data points, then $K(u_k, v_p)$will be small. So the selection of additional weights in the cluster center has been optimized using the Dragonfly optimization.

Dragonfly Optimization:

Dragonfly optimization is a metaheuristic optimization used to optimize the different real world problems by Mirjalili. In this teeth segmentation, the additional weights in the clusters of FCM has been optimized using DO. Dragonflies possess exclusive swarming features with two functions: migration (dynamic migratory) and hunting (static feeding) (Mirjalili 2015). Optimization with Meta-heuristic approach has two stages like exploitation and exploration. In dragon flies, migration and hunting are similar to the above mentioned stages.

To show the dragonflies swarming characteristics, three primitive swarming standards are given: alignment (A), separation (S) and cohesion (C). It also considers two ideas: distraction external enemies (E) and attraction in food sources (F) direction to acquire swarm survival rate. Mathematical formulation of designing these features for individual swarm location is illustrated in (Mirjalili 2015).

The mathematical formulation is as

$$Y_{t+1} = (sS_i + aA_i + cC_i + fF_i + eE_i) + w\Delta Y_t \qquad (8)$$

Where ‘s’ defines weight separation, S_i specifies ith individual separation, ‘a’ specifies weight alignment, A_i specifies ith individual alignment, c specifies cohesion weight, C_i

specifies ith individual cohesion, 'f' specifies food factor (i.e. effectual weight), Fi specifies food source of ith individual, e represents opponent feature, E_i specifies i^{th} individual opponent position, w specifies inertia weight, t specifies repetition counter.

$$\Delta Y_{t+1} = Y_t + \Delta Y_{t+1} \quad (9)$$

Algorithm 1: Segmentation of Teeth using kernel based Fuzzy C-means clustering with Dragonfly Optimization

Input: Teeth Image pixels

Output: Centroid of Image pixels Cluster

Method: Initialize the parameter values such as the number of cluster centers c, t as max number of iterations, m>1and Ɛ>1 (convergence threshold)

1. Set t=0
2. Set the fuzzy membership value as X_{pk}^{0} and v_p
3. While $\|X^t - X^{t-1}\| > Ɛ$ do
4. t= t+1
5. Calculate primitive standards of swarming, separation (S), alignment (A) and cohesion (C)
6. The optimal solution of location are attained and compute positive vectors
7. Calculated the objective function using alignment, separation and cohesion weight, food and enemy factor, inertia weight using the equation (8)
8. If $Y_{t+1}$is better than Y, then Y=Y_{t+1}
9. Randomly select the position using the equation (9)
10. Choose this value as optimal for
    a) Update the Cluster center values using the equation (7)
    b) Update the membership values X_{pk}^{m}using the equation (6)
11. Perform threshold value for classifying the clusters using Equation (5)
12. Whole teeth has been segmented and post morphological processing has been utilized for better accuracy of segmentation

3.5 Feature Extraction

Features are an important for age classification. In this, Features are used as classification input. Certain feature in this segmented teeth image such as Haralick features, GLCM, Haufsdroff distance, crown, density of tooth and extent. Linear structures like concavity, irregularity, convexity, region and edge of the tooth are taken out.

3.6 Feature Classification using ENN-GCPSO

Based on the extraction of features, the dental age has been identified using ENN classifier. In order to progress the exactness of ENN, GCPSO is introduced. The classification results have been foreseen and performance of the results is compared with the existing classifiers and also with the existing Demirjian method.

Elman neural network is feed forward network with an input layer, a hidden layer (undertake layer), an output layer and a special layer called context layer. The output of each hidden neuron is copied into a specific neuron in the context layer. In an Elman network, the weights from the hidden layer to the context layer are set to one and are fixed because the values of the context neurons have to be copied exactly. The Elman network can be trained with gradient descent back propagation and optimization methods. [26]

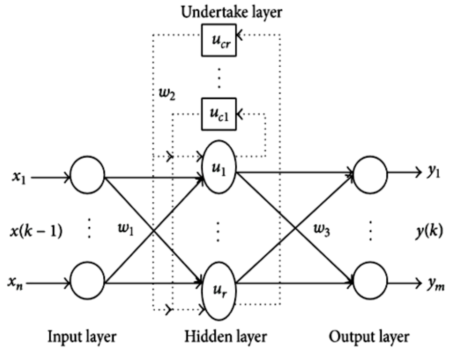


Fig.2: Architecture of ENN

The fig.2 shows the architecture of Elman Neural Network. Suppose with n input, m output, the number of hidden and undertake neurons are r, the weight of input layer to hidden layer is w_1, the weight of undertake layer to hidden layer is w_2, the weight of hidden layer to output layer is w_3;$u(k-1)$ is the input of neural network, $x(k)$ is the output of hidden layer, $x_c(k)$ is the output of undertake layer, and $y(k)$is the output of neural network; then

$$x(k) = f\left(w_2 x_c(k) + w_1\big(u(k-1)\big)\right) \quad (10)$$

Where $x_c(k) = x(k-1)$

$$f(x) = (1 + e^{-x})^{-1} \quad (11)$$

f is the hidden layer transfer function, which is commonly used in S-type function; that is,

g is the transfer function of output layer, which is often a linear function; that is,

$$y(k) = g\big(w_3 x(k)\big) \quad (12)$$

Elman neural network uses BP algorithm to review weights; the network miscalculation is

$$E = \sum_{k=1}^{m} (t_k - y_k)^2 \quad (13)$$

Where tk →output vector of object.

To improve the exactness of ENN expectation, Guaranteed Convergence Particle Swarm Optimization (GCPSO) takes practiced for augmenting the weight value of ENN.

Optimal Weight selection using GCPSO

The weight values and improving the accuracy in ENN classifier have been optimized using Guaranteed Convergence Particle Swarm Optimization (GCPSO).

In PSO, if the particle's position is as same as global best position, then all the particles will stop moving, but premature convergence to a position is not guaranteed to be the best position or a local optimum. This stagnation problem can be resolved by incorporating a parameter τ in the PSO algorithm called GCPSO [27]

Consider τ be the index of the global best particle,

$$A_\tau = G_{best} \quad (14)$$

An updated velocity equation has been proposed based on A_τ. By keep moving A_τ until it has reached a local minimum. [28]

$$v_{\tau j}^{t+1} = -x_{\tau j}^{t} + G_{best}^{t} + \omega v_{\tau j}^{t} + \rho^{t}\left(1 - 2r_{2j}^{t}\right) \quad (15)$$

Where,

ρ^t → Scaling factor

$-x_{\tau j}^{t}$→ Particle's position to the G_{best}^{t}

$\omega v_{\tau j}^{t}$ → Current search direction

$\rho^{t}\left(1-2r_{2j}^{t}\right)$ → Random sample

The updated position of the particle equation

$$x_{\tau j}^{t+1}=G_{best}^{t}+\omega v_{\tau j}^{t}+\rho^{t}(1-2r_{2}^{t}) \qquad (16)$$

ρ^{t} is a parameter to control the diameter of the search space that will be searched random manner.

Algorithm2: ENN-GCPSO based Dental Age classification

Inputs: A training set of n classes $A=[A_1,A_2,..,A_n]$, a test sample T, hidden feature number H, activation function k(x)

Output: Dental age identification

Method:

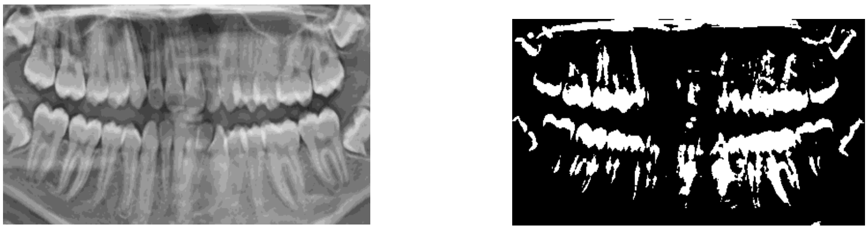
1. At first randomly generate the hidden feature constraints (i.e. w_i, r_i)
2. Fix the objective function as f(x)
3. Set position and velocity for the population in the possible section.
4. Prepare the P_{best}^{t} and G_{best}^{t} and τ
5. When $x_{i,j}(t)=P_{best,i}^{t}=G_{best}^{t}$, then updated the velocity and position using equation (14)
6. Calculate the updated velocity using equation (15)
7. Calculate the updated position of the particle using equation (16)
8. Calculate the success and failure count using ρ^{t} to apprise the best position and velocity of the particle.
9. Update P_{best}^{t+1} and G_{best}^{t+1}
10. Stagnation is prevented, when $\rho^{t}>0$
11. Find the optimal weight for the ENN using G_{best}^{t+1}
12. Dental age is classified and accuracy is predicted.

Outcomes And Disclosure

In this, the expected DA classification method is tested and compared with other classifiers such as ENN-DO, MELM-SRC, RBFN and ANFIS. At first, OPG images of teeth are enhanced and examined. All the actions are calculated using MATLAB. Here, 100 samples of teeth images are taken for calculation. Upon which, 75 trials of OPG are used for training then 25 trials of OPG are used for testing phase with ENN-GCPSO classification.

Input OPG Tooth Image   Filtered Image

Pre-processed using ADF   KFCM-DO output



Morphological post processing　　　　Age detection result

Fig.3: Results of input teeth image using ENN-GCPSO

Fig. 3 shows the results of ENN-GCPSO classification.Complete performance calculation for DA detection using ENN-GCPSO is performed in Figure10. It shows that predicted ENN-GCPSO has attained higher enactment with 89% of exactness, 84.5% of specificity, 66.41 % of precision, 89.6% of recall and 73% of f-measure compare to other classifiers such as ENN-DO, MELM-SRC, RBFN and ANFIS.

Performance Matrices	**Proposed ENN GCPSO**	**ENN-DO**	**MELM-SRC**	**RBFN**	**ANFIS**
Accuracy %	89	85	80	72	40
Specificity %	84.5	82.25	80.14	70.99	40.53
Precision %	66.41	64.18	44.42	38.79	19.51
Recall %	89.6	90.25	69	61.33	34.33
F-measure %	73	69.43	53.66	44.47	25.5

Table 1: Overall performance metrics for DA detection

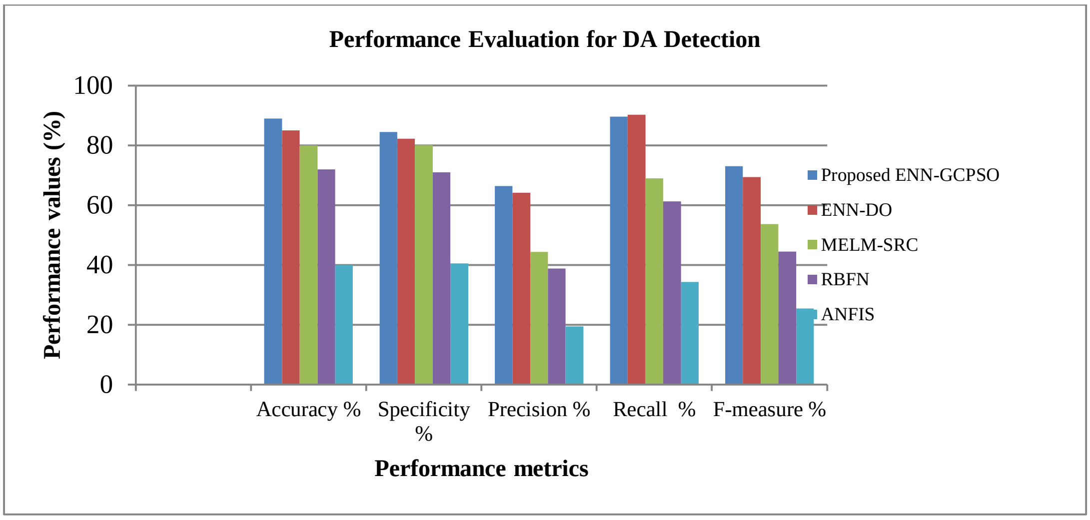


Fig.4: Performance Evaluation for DA detection using Proposed ENN-GCPSO

4. CONCLUSION

In this, ENN-GCPSO has been proposed for detecting the dental age of the person and compared it with chronological age of the same person. OPG teeth image is initially preprocessed using ADF for removal of noise without eradicating the edges. The enhanced whole teeth image is segmented by Kernel based FCM. In this, choosing of cluster center issue is resolved by Dragonfly optimization and morphological post processing is applied to enhance the segmentation accuracy. Hence, selected features are extracted for classification. ENN has been utilized for DA classification and optimal weights have been selected for ENN by GCPSO optimization in order to progress the expectation precision. The investigational outcomes indicate that the anticipated ENN-GCPSO has 89% of accuracy than the existing classifiers such as ENN-DO, MELM-SRC, RBFN and ANFIS. In forthcoming work, the number of samples has been increased to predict the precision results and experiment by new-fangled algorithms.

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