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Research Article

Classification of Digital Intra Oral Periapical Radiographs Represented as Feature Vector Using Neural Network Architectures: A Comparative Study

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Abstract

Study of various multi-layer perceptron neural network architectures and their comparison for classification of Intra Oral Periapical radiographs (IOPA) where individual tooth in that radiograph is represented by its feature vector.

In this paper input vector for the neural network is a seven dimensional feature vector of individual tooth. Data vectors are distributed in ratio 4:1 for training and testing purposes. The data used for testing is redistributed in 3:1 ratio for training and validation. Four different neural network architectures are compared based on their performance for the same data set. Neural networks realized in this paper are perceptron classifier using threshold logic neuron, perceptron classifier using threshold logic neuron with tower algorithm for structure growing, feed forward neural network and back propagation neural network.

Multi-layer perceptron neural network architectures are tested on 10 radiographic images containing healthy as well as diseased tooth. 30 images are used for training and 10 images are used for validation. The classification algorithm presented in this research work is a two class classifier. This algorithm can be very easily adopted for multi class classification by calling the same repetitively using the classification strategy one against rest.

Architectures used in this paper differ in selection of activation logic for hidden layer neurons and output layer neurons. Input layer in all architectures comprises of linear neurons. Hidden layer neurons are threshold logic neurons or sigmoidal neurons. Output layer neurons are threshold logic neurons. The algorithm can be improved by designing multi-class classifier for the same data.

Keywords: *Intra Oral Periapical Radiograph; Feature Vector; Threshold Logic Neuron; Sigmoidal Activation Neuron; Tower Model Architecture of Neural Network; Multi-Layer Perceptron Classifier*

Abbreviations

IOPA: Intra Oral Peri Apical; GLCM: Gray Level Co-occurrence Matrix; ANN: Artificial Neural Network

Introduction

Digital intra oral periapical radiographs are administered on dental patients when the need is felt to do so, by dental practitioners. The experience and knowledge of a dentist plays an important role in reading the radiograph. Visual perception of the image data seen in the radiograph helps locate abnormalities and diagnoses the disease.

Complete automation of the process of diagnoses of the disease is state-of-the-art research area in image processing and artificial intelligence. Designing and building artificial neural network to classify dental radiographic images in two classes, is the focus of the study. Different architectures of multi-layer perceptron neural networks are analysed in this paper.

After the literature survey was carried out on various applications using neural networks for classification of numeric as well as image data, a need was felt to design an appropriate neural network for classification of IOPA. IOPAs can be classified into various classes such as IOPA of a healthy tooth, a carious tooth, a tooth with dental work; IOPA of a molar, a premolar, a canine, an incisor and IOPA of an impacted tooth, an extracted tooth, etc. In this paper an attempt is made to preset a methodology to compare and select appropriate neural network architecture for IOPA images containing exactly one tooth in one image.

In research paper [1], researchers have developed a system for extracting features from dental radiographs. The system worked in two phases, segmentation and feature extraction. In segmentation module researchers have used k-means clustering method to form five clusters based on intensity or grey level at that pixel. GLCM is used for feature extraction. Five features were extracted for each image. The present research work provides a simpler method to extract features of single tooth classifying it as diseased or healthy.

References [2-4], discussed various neural networks as tools, used in applications in dental radiograph processing. The applications were, to analyze disease from dental radiograph using particle swarm optimization and back propagation neural network [2], to detect dental abnormalities from radiographs using support vector machine and back propagation neural network [3] and to detect edges from dental radiographs using artificial neural networks [4]. It was required to develop an algorithm using artificial neural network as tool to work on digital dental radiograph rather than using binarization of image.

Authors in their research paper [5] presented a literature survey of comparison of various methods for the identification and classification of cancers. Methods to detect brain tumour, breast cancer and oral cancers were compared. Techniques used for detection were image processing, image processing along with neural networks, neuro-fuzzy and image processing along with data mining and neural networks. A need was felt to develop algorithm using image processing along with image data mining and neural networks.

Paper [6] presented a novel framework which uses graph based clustering method on dental x-ray images for disease diagnosis. Steps followed by authors were to generate a dental feature database of dental X-ray images, to use a vector quantization algorithm to clarify the principal records from the database, to model the principal records as nodes in a graph, to apply a graph-based clustering algorithm to classify the graph according to the disease patterns, to determine the disease for the new X-Ray image, to implement three variants of the framework namely Prim spanning tree, Kruskal spanning tree and Affinity Propagation Clustering (APC), to apply the methods on the real dataset and evaluate the performance and then suggest the best method in term of accuracy. In this paper attempt is made to develop intelligent method for classification of digital dental radiographs for disease diagnosis.

In [7] authors have presented a new fast algorithm for detection of dental diseases. This algorithm works on concept of performing cross correlation in the frequency domain. The cross correlation is established between input image and the input weights of fast neural networks (FNNs). Researchers proved mathematically and practically that, the number of computations required for the FNNs are less than the number required by conventional neural networks (CNNs). Input images were digitized dental radiographs. Authors used digital subtraction radiography for noise removal. CNNs are trained to classify sub images which contain diseases and sub images which do not contain diseases. This training algorithm works in the spatial domain. Cross correlation was established between sub image and input weights. The number of weights was equal to size of sub image i.e. each pixel of sub image is input to neural network. With the advent of technology, digitization of image is not needed; as a result of this, it is required to work with digital dental radiographs using intelligent tools.

In paper [8] authors have shared the research results of diagnosis based on medical imaging. Researchers have summarized the current pattern recognition diagnostic methods based on medical imaging. They have used pattern extension recognition diagnosis methodology for medical imaging. Two basic methods, statistical pattern recognition diagnostic method and structure (syntax) pattern recognition diagnostic method based on medical imaging are discussed. Authors stated that artificial neural network was more useful tool as compared to minimum distance classifier and Mahalanobis distance function for application in pattern recognition diagnosis based on medical imaging. It was required to build an ANN for diagnosis of IOPA images.

Reference [9], was a special edited issue on neural networks for data mining and knowledge discovery. The goal of the methods and algorithms on data mining and knowledge discovery was to extract useful regularities from large data archives, either directly in the form of "knowledge" characterizing the relations between the variables of interest, or indirectly as functions that allow to predict, classify or represent regularities in the distribution of the data. The challenges for information and computer science, statistics and algorithmics in the new field of data mining and knowledge discovery were discussed. The application areas in this field were discussed.

In [10], for knowledge discovery and data mining Logistic regression, CART and ANN were compared for caries prediction. Training and validation were performed with a 70% - 30% randomly split sample stratified on primary dentition caries. All methods used the same training data to develop the prediction models and the hold-out validation data to validate the models. For longitudinal caries risk assessment study the input data for kids up to 6 years, were generated from collected saliva and also from dental examinations performed without radiographs, every six months.

In reference [11,12], hybrid method is used for extracting features of single tooth IOPA and perceptron classifier is developed to classify such tooth as healthy or unhealthy. Algorithm to segment IOPA into multiple images, each image containing exactly one tooth is discussed in research paper [11]. While as in paper [12] hybrid method of selecting a feature vector for appropriate representation of IOPA in feature space is discussed.

In this paper performance analysis of four different neural networks for classification of a tooth is presented. Tower model for structure growing, feed forward neural network and back propagation neural networks are compared for classification of image data, distributed nonlinearly in original parametric space.

Materials and Methods

The algorithm developed in this paper consists of four modules. The input to the algorithm for classification of IOPA is a hybrid feature vector. The digital IOPA radiograph is having exactly one tooth in one image. The four modules are shown in figure 1.

Block Diagram

The block diagram indicates modules involved in design and analysis of two class classifiers realized using perceptrons as basic building unit for artificial neural networks. The input for first module is a feature vector of IOPA radiograph of a single tooth.

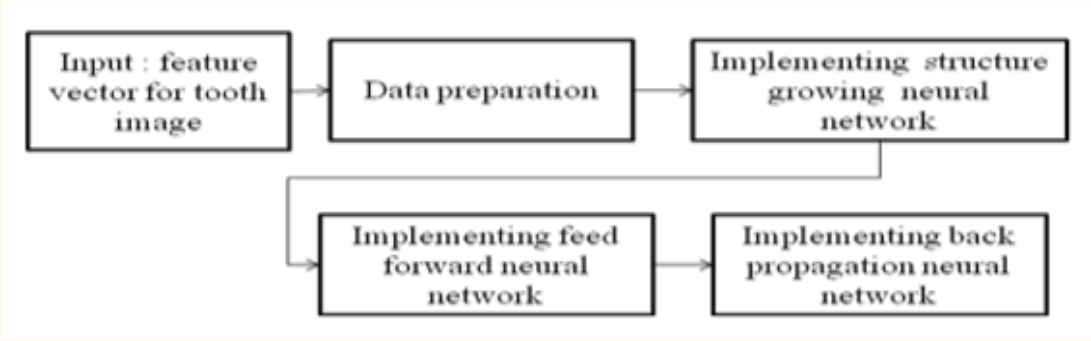

Figure 1: *Block Diagram of System.*

Data Preparation

First module shown in the block diagram prepares the input data for presentation to the input layer of a neural network. Performance of a neural network depends on quality of input data to some extent. Data cleaning, handling noise in the data, data scaling and feature reduction are the main issues involved in data preprocessing [13]. The input data for neural network in this research work is seven dimensional feature vector for digitally recorded IOPA of single tooth. The preprocessing of data for cleaning and noise handling is not required as feature vector attributes are derived from digitally recorded IOPA radiograph. Data scaling for all attributes of the feature vector is required as attribute values require normalization. The mean and standard deviation approach is used for data normalization as there are outliers in the values of some of the feature attributes. Further reduction of features is not required as input is not given in its original parametric space but in feature vector form.

Neural network: structure growing

Neural networks realized in this paper are perceptron classifier using threshold logic neuron and perceptron classifier using threshold logic neuron with tower algorithm for structure growing. Neural network architecture realized in this module is designed for classification of single tooth radiograph, into IOPA of a healthy tooth or IOPA of a diseased tooth. The architecture is a structure growing architecture also known as tower model.

Structure growing algorithm is used for classification of each tooth as healthy or unhealthy. The input layer of this neural network has 11 linear neurons connected to one threshold logic neuron using synaptic weights. Initially this neuron is trained to give optimum solution. After that a new threshold logic neuron is added to the system. This neuron works with original 11 inputs and one additional input. This additional input is output of the neuron trained in earlier stage. This neuron is trained with 12 inputs. The process of introducing one new neuron at each stage is repeated till no further classification accuracy is attained. At each stage the newly added neuron gets input from 11 original input neurons and an additional input from its immediate predecessor threshold logic neuron added in earlier stage.

Neural network: feed forward and back propagation

Neural network architectures realized in these modules are designed for classification of single tooth radiograph, into IOPA of a healthy tooth or IOPA of a diseased tooth. The architectures are feed forward neural network and back propagation algorithm to propagate error back words.

In back propagation algorithm input layer is made up of 11 linear neurons. In hidden layer there are 2 threshold logic neurons. Output layer has one threshold logic neuron to classify each tooth as healthy or unhealthy e.g. carious tooth, extracted tooth and tooth with artifacts. Statistical feature input neurons were connected to one threshold logic neuron in hidden layer and structural feature input neurons were connected to other neuron in hidden layer. Output layer neuron is connected to both the neurons in hidden layer.

Neural network: comparison of approaches

The network architectures discussed in section 5.3 and 5.4 are realized using MATLAB. The data set is distributed into training data set and testing data set. The same data set is used for realizing both the architectures. Training and testing data set are prepared such that they will be having 10% common data. Of the entire data space the distribution is done in the ratio 3:2 for training and testing.

Results and Discussion

Structure growing algorithm tower model successfully classifies non-linear data set of IOPA radiographs. The classification is done as IOPA of healthy tooth and IOPA of unhealthy tooth. Feed forward neural network and back propagation neural network also successfully classifies the radiographs. MATLAB tool is used for determining and comparing the computational complexity of the algorithms. Feed forward neural network with back propagation proves to be more efficient. The table 1 demonstrates these results.

Neural network architecture	Number of images correctly classified	Run and time option in MATLAB 2013a
Perceptron classifier	16	100 secs 1000 epocs
Tower model for structure growing	18	8 secs 710 epocs
Feed forward network	18	10 secs 500 epocs
Back propagation network	18	10 secs 380 epocs

Table 1: *Showing comparison of four neural network architectures.*

Conclusion

Various researchers have published literature on different methods to analyze biomedical images. All researchers agreed upon the fact that image classification is a critical step in image analysis. They also agreed that selecting appropriate algorithm for specific data set is critical task. A comparison between four supervised learning algorithms for classification of IOPA radiographs is presented in this paper. The structure growing architecture based on tower model works better than remaining three algorithms, perceptron classifier, feed forward neural network classifier and back propagation neural network classifier when the data needs to be classified in two classes. The structure growing algorithm handles the non-linearity in data and works perfectly fine for IOPA radiographs. The algorithm works on digital periapical radiographs, classifying each tooth as a healthy or non-healthy. Such single tooth classification is very useful in medical field in disease diagnosis and treatment planning. The algorithm does not work so well in differentiating between carious tooth and tooth with dental work as these type of images are classified under single category of non-healthy tooth images. Feed forward neural network and back propagation neural network works well in this domain. These algorithms classify images with dental work, extracted tooth and carious tooth as non-healthy tooth images.

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Conflict of Interest

Nothing to declare.

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