Microprocessors and Microsystems 82 (2021) 103836

Contents lists available at ScienceDirect

Microprocessors and Microsystems

journal homepage: www.elsevier.com/locate/micpro

Learning compact and discriminative hybrid neural network for dental caries classification

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ARTICLE INFO

Keywords:
Dental caries
Hybrid neural network
Logistic regression layer
Stacked sparse auto-encoder
Feature Extraction
Classification

ABSTRACT

Dental caries, alternatively called tooth decay is considered as the most general and rapidly increasing diseases. According to the statistics, nearly 90% of the adults confront the issue of dental caries. Hence for proper dental care and health, early detection and diagnosis concerning the caries lesion plays a mandatory role. To achieve this, technique of Imaging Processing is being adopted which further helps the specialists to carry out precise diagnosis. Dental Caries can be categorized into different types depending on its position as well as seriousness. This categorization holds significant to carry out diagnosis and plan for the treatment of dental disease. The paper recommends the new HNN (Hybrid Neural Network) technique for detecting dental caries depending on, its type and therefore precisely classify the caries affected layer. HNN is a blend of ANN (Artificial Neural Network and DNN (Deep neural network) techniques. To obtain image classification, deep neural network relies upon the stacked sparse auto-encoder. Thereafter authentic information can be fetched from data via supervised fine-tuning and unsupervised pre-training. On the other hand ANN (Artificial neural network) relies upon the logistic regression for classifying the dental caries affected layer. Various processes involved in dental input image are as following: l. Pre-Processing, 2. Segmentation, 3. Feature Extraction and 4.Classification. Caries are categorized into 4 different layers by the HNN, namely: Enamel, Dentin, Pulp and root lesions. The proposed system yield in effective output against the input image provided and precisely categorizes the caries level. Hybrid neural network is the innovative technique which is giving good result in terms of accuracy and processing time.

1. Introduction

With the rapid increase in the field of technology, the Image processing techniques have gained immense success and popularity in numerous applications. Dental caries alternatively considered as the most general and rapidly increasing disease. The food present in the teeth is broken down by the bacteria (present in plaque) which then generates acids and severely damages the hard tissues surrounding the teeth resulting in tooth decay or dental caries [1]. Almost 60–90% of school children are being affected by this wide spreading disease which is till date considered as an intense health issue (Aeini et al. 2010). Lately, technique of Image processing has been adopted in dentistry for early detection and diagnosis concerning the dental caries/oral related diseases ([2] and [3]). It basically specifics/classifies the type of dental disease infections. Numerous researches have been performed for the detection of dental caries pertaining to tough cases and multiple methodologies are recommended for the classification of dental caries. But no such method is capable enough to precisely classify the caries layer wise. Though lately, various ML (machine learning) techniques are incorporated for classifying and analyzing the image data. Among these the ANN (Artificial Neural Networks) and DNN (Deep Neural Network) models of ML technique ascertains to be of utmost significance. In spite of numerous available techniques for early detection of caries, it's essential to construct a precise caries detection technique, beneficial for the dentist.

Following is the structure of the paper: Section 2 gives an overall Literature Review. Section 3, elaborates the recommended methods and illustrates how the dental images can be trained and classified by employing HNN (Hybrid Neural Network) along with stacked sparse auto-encoder and logical regression classifier. Section 4 contains the simulation and experimental results obtained and further discussions. Section 5 contains the conclusion of the paper.

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https://doi.org/10.1016/j.micpro.2021.103836
Received 26 October 2020; Received in revised form 26 December 2020; Accepted 4 January 2021
Available online 5 January 2021

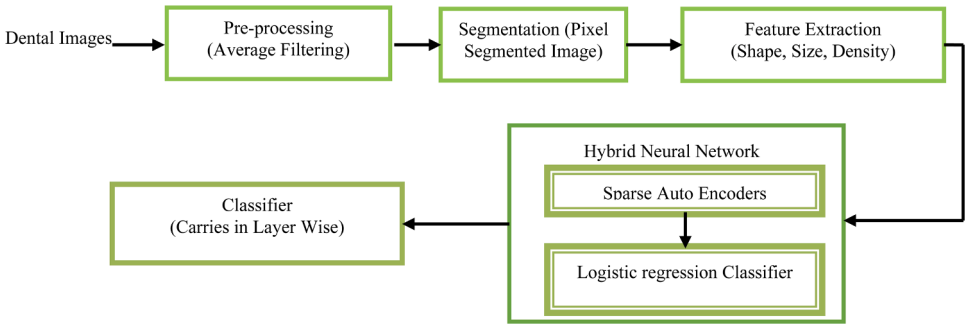

Fig. 1. Dental Caries Classification System Architecture.

2. Literature review

The literature presents multiple techniques built for detecting the dental caries. Every tooth has four basic

Layers: Enamel, Dentin, Pulp and root [4]. Small lymph vessels carry white blood cells to the tooth to fight against germs and bacteria ([5] and [6]). Kositbowornchai et al. [7] built a neural network which could identify artificial dental caries by utilizing images fetched from a CCD (Charged Coupled Device) camera and intra-oral digital radiography. Saravanan et al. [8] built a new technique for dental caries detection at an early level by adopting histogram and power spectral analysis. Berdouses et al. [9] built a computer-based automated technique to detect and classify the occlusal caries taken from photographic color images. Shuo Li et al. [10] propose an automatic variation level set segmentation framework for CADXA (Computer Aided Dental X- rays Analysis).

Abdolvahab Ehsani Rad et al. [11] put forwards that shortage of image database stands as the most challenging factor concerning dental image analysis. P.L.Lin [12] proposes a dental classification and numbering system that considers dental bitewing radiographs in order to segment, classify, and to number teeth. Lin et al. [13] propose an improvised dental identification technique on the basis of the contours of teeth and dental work. In order to minimize the alignment error from unpredictable contours, a point- reliability measuring technique is being proposed. AbdolvahabEh et al. allows comprehending various image segmentation methodologies adopted for dental X-ray image analysis. Shah et al. [14] considers and converse about an automated dental identification system. Shengguo Chen et al. [15] put forwards the algorithm of a semi-supervised image segmentation which is adopted to segment the noisy image. Tran Manh Tuan et al. [16] proposes a new SSFC-FS (semi-supervised fuzzy clustering) algorithm that relies upon Interactive Fuzzy fulfilling the dental X-ray image segmentation concern. A. J. Solanki et al. conducted ISEF edge detection in order to examine the depth of dental caries in a decayed tooth. With the help of edge detection, the border pertaining to dental cavity can be retrieved along with identifying number of pixels affected by the caries [17]. Bardia Youseif et al. [2] formulated a technique for image enhancement of digital dental X-ray by adopting the wavelet image fusion and Bayesian classifier. As a result the Laplacian transform was implemented on the image, and thereafter structure element followed by morphological operation was employed (Dighe et al. 2012 and [18]). The image acquired was merged by utilizing wavelet transform long with input image and subsequently Bayesian classifier was employed for classifying teeth and canals from the image obtained.

3. The research method

3.1. Overview

Dental X-ray images helps in identifying and analyzing the limit to which the caries lesion exist in the dental radiograph. There exists a wide scope of Image processing applications in the field of dental radio graph and when applied correctly, it enhances the diagnostic results and offer perception related to various phases of the imaging process that being restricted in the diagnostic domain. The proposed architecture is shown in Fig. 1. The dental X-ray image serves as the input image for the Pre-processing stage.

3.2. Pre-processing

Filtering technique is a complex function, which being employed to remove any noise in the images. Filter works to generate absolutely clear and smooth images. Here the image is forwarded as input on which the filtering method is applied so as to generate output with least noise image. At first, gray scale image is converted into normalized image as output then blur effect is reduced. Selective median filter is used to remove the noises in the images. Selective median filter [19] act as a median filter for the pixel values 0 and 255 and for other pixel values it acts as a wiener filter.

$$\text{SelectiveMedianFilter} = \begin{cases} \textbf{MedianFilter} & \text{for} \quad p(x) = 0 \text{and} 255 \\ \textbf{WienerFilter} & \text{otherwise} \end{cases} \tag{1}$$

3.3. Segmentation

In Segmentation process the dental image is segmented or divided into its constituent pixels or objects. Thresholding is utilized to generate binary images, taking in account the gray scale image and for that it considers the space regions that are relying upon the image's characteristics [20]. Thresholding techniques are used to detect the cavity regions present in the image.

3.4. Feature extraction

. Feature extraction process deals with extraction of distinct features of a dental image. Following attributes are considered for computing the features, these are: shape, size and density.

3.5. Classification

Classification techniques help in identifying the caries type depending on its position. The classification relies upon some specific conditions such as, whether the lesion exists inside the enamel and dentin or if it touches the pulp [21]. Caries are classified into 4 different layers by the HNN, namely: Enamel Dentin, Pulp and root lesions.

3.5.1. Hybrid neural network

This Section illustrates and encourages utilizing DNN (deep neural networks) with multiple hidden layers for training and classifying the dental images. HNN is a blend of ANN (Artificial Neural Network and DNN (Deep Neural Network)) techniques. Using such techniques a HNN can be trained.

Deep Neural Network: DNN (Deep Neural Network) is a neural

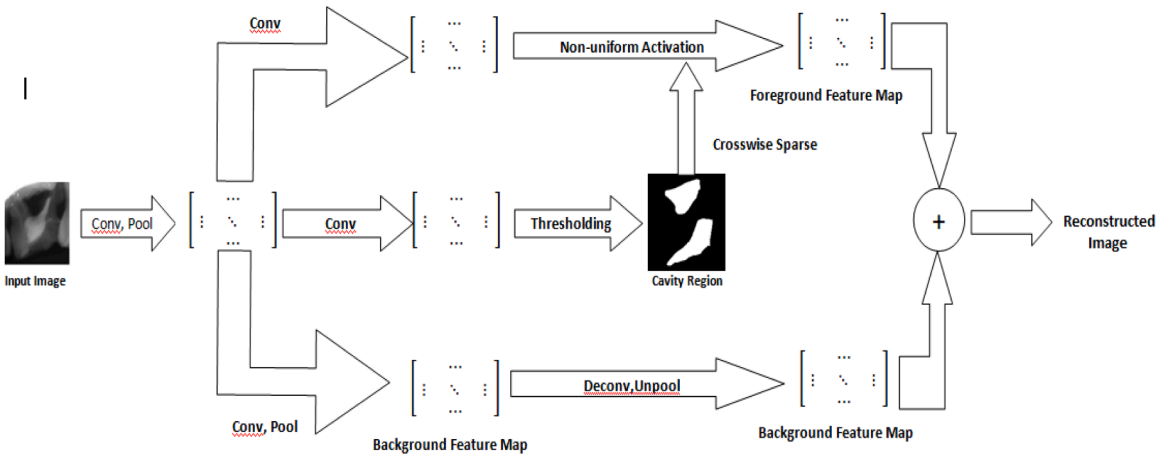

Fig. 2. Architecture of Neural Network.

network with two or more layers and having a specific complexity level. Here, every layer of nodes trains unique group of features relying upon the output of the previous layer. To train the input image, DNN relies upon the stacked sparse auto-encoder.

Artificial Neural Network: Every neuron denotes a pixel. There exists one non-linear hidden layer in which the entire neurons relies upon radial distance functions. ANN (Artificial neural network) relies upon the logistic regression for classifying the dental caries affected layer [22]. **(a) Stacked Sparse Auto-Encoder**

A stacked auto-encoder is a symmetrical neural network learns the dataset features in an unsupervised way [23]. In the present work, DNN utilizes SSAE (stacked sparse auto-encoder) that is trained in an unsupervised manner for extracting hidden features [24]. It detects and encodes cavity in image patches in the dental images into sparse feature maps that encode both the appearance and location of the cavity [25]. Stacked sparse auto encoder is used here to detect the cavity and it learns the features in a single network and can be taught end-to-end without supervision. In the first SSAE trained to learn the background and cavity in an image patch, as shown in Fig. 2. Initially thresholding technique is used to detect the cavity regions in the given image. Remaining regions are considered as the background. Cavity and background regions are multiplied in the crosswise sparse manner. All the neurons in the feature maps are not activated uniformly. Foreground regions are activated and backgrounds regions are not activated [26]. This technique enable to highlight the foreground than background. 6 Convolution and 2 pooling layers are used in the initial stages of neural network. In the final stage, it is divided into three feature maps, first one is the detection map, second one is the background map and the third one is the foreground map. Foreground map and background map are combined as reconstructed image and presented as the output. Reconstructed image is obtained by summing the foreground and background images [27].

(b) Logistic regression Classifier

Logistic regression is a predictive analysis to define the relation amidst both dependent and independent variables. There exists a single dependent variable and one or more independent variable. The Logistic regression classifier aids in classifying the layer affected by dental caries. Though the Adaptive Coefficient will comprise the essential features, help to enhance the classifier's accuracy. Logistic regression classifier is

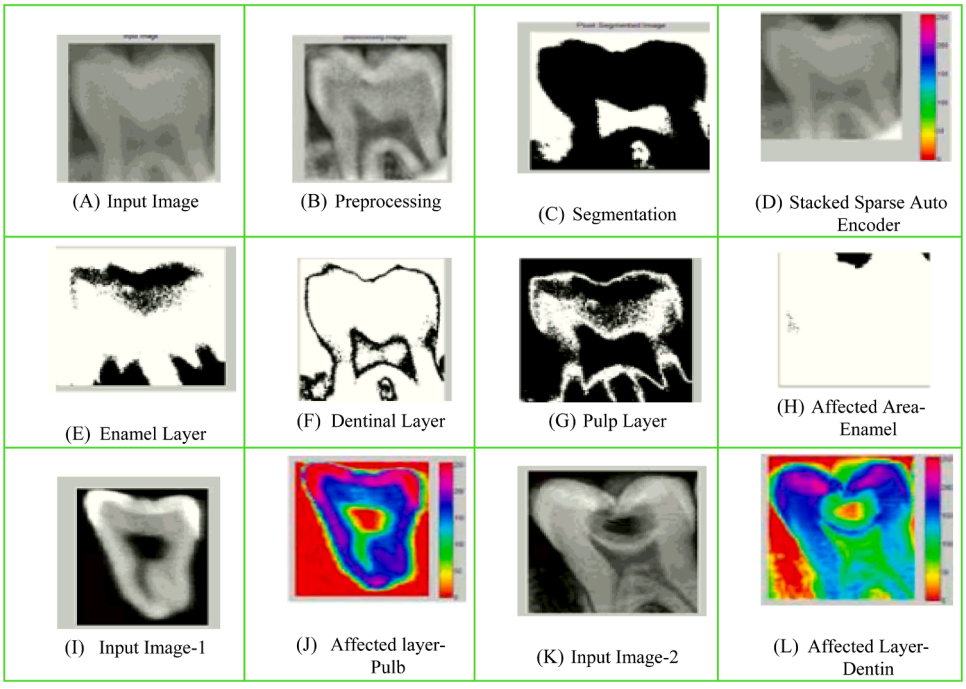

Fig. 3. Simulation Process.

Table 1
Comparison of Performance Results.

S no	Techniques	Accuracy (%)	Mean processing time (msec)
1	Convolution Neural network	78	1.234
2	Multi layer Perceptron Neural Network	85	0.956
3	Hybrid Neural Network	96	0.732

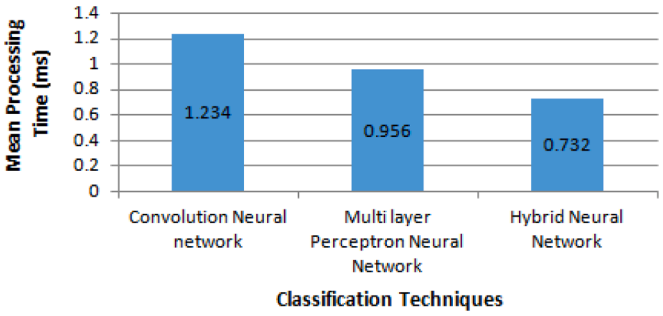

Fig. 4. Time calculations.

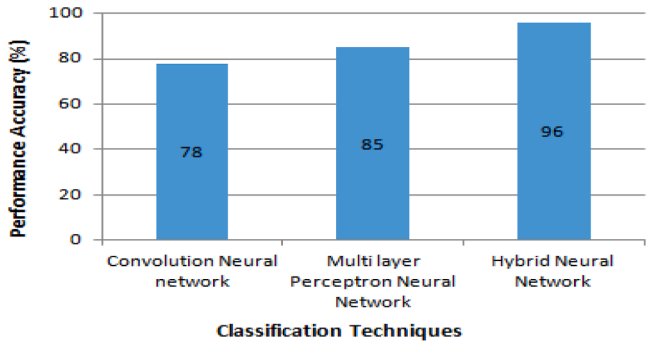

Fig. 5. Comparison of classification Techniques.

used to fine tune the unsupervised result obtained through the stacked sparse auto encoder [28].

4. Results and discussion

4.1. Simulation results

The datasets are collected from the work done by Ching et all [18] and given in the website (http://www-o.ntust.edu.tw/~cweiwang/ISBI2015/).In the dataset 80 images are given.40 images are available in training data set and 40 images are available in testing dataset. Each image consists of six or more tooth. Each teeth image is divided into six tooth images in order to make the process easy. Final datasets contains altogether 480 dental images300 images are taken for training and 180 images are taken for testing. Around 173 images are classified accurately, detecting them layer wise with precise outcome. Entire development is performed in the MATLAB environment as a result retrieval of significant medical data is available. Fig. 3 shows the simulation result.

Fig 3, depicts the output of simulation process, the segmented image and the caries affected image. (A) (I) (K) input dental images. (B) Preprocessed image-aids in removal of noise. (C) Pixel based segmentation image by hiding the background images. (D) Feature extraction image-this being beneficial for extracting the outlier based pixel values. (E)(F)(G) Three layers namely Enamel, Dentinal and Pulp (H) Caries Affected regions-Enamel. (J) Caries Affected regions-Pulp. (L) Affected regions-Dentin Table 1

Fig. 4 mentioned below depict the comparison of the performance of HNN (hybrid neural network) techniques in contrast with the CNN (convolution neural network) and Multilayer perception neural networks in the mean processing time value. The proposed HNN techniques took minimum average time than the traditional technique like CNN and multilayer perception neural network. Fig. 5 mentioned below depict the comparison of the performance of HNN (hybrid neural network) techniques in contrast with the CNN (convolution neural network) and Multilayer Perception Neural networks. The proposed HNN technique yields in effective and improvised performance in contrast with rest of the techniques.

5. Conclusions

Dental cavity tends to be a rampant disease affecting numerous individuals all over the world. Early detection and diagnosis concerning the caries lesion plays a mandatory role in the treatment of the same. Hence the methods for caries detection must be effective enough to detect lesions at the earliest. The present paper recommends the HNN (hybrid neural network) which being a blend of DNN (deep neural network) and ANN (artificial neural network) for detecting the dental caries by adopting the capability of image processing. The ML (machine learning) techniques like DNN(deep neural network) employs stacked sparse auto-encoder unsupervised and supervised fine-tuning and ANN (Artificial Neural Networks)employs logistic regression that basically classifies the dental caries affected layer. The proposed system yields in effective output against detecting caries type depending on its position thereby classifying the level of the caries existing in the dental image.

Conflict of interest and authorship conformation form

Please check the following as appropriate:

1 All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.
2 This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.
3 The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript
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Declaration of Competing Interest

None.

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