

Caries Detection from Dental Images using Novel Maximum Directional Pattern (MDP) and Deep Learning

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ABSTRACT- Various machine learning technologies and artificial intelligence techniques were applied on different applications of dentistry. Caries detection in orthodontics is a very much needed process. Computer-aided diagnosis (CAD) method is used to detect caries in dental radiographs. The feature extraction and classification are involved in the process of caries detection in dental images. In the 2D images the geometric feature extraction methods are applied and the features are extracted and then applied to machine learning algorithms for classification. Different feature extraction techniques can also be combined and then the fused features can be used for classification. Different classifiers support vector machine (SVM), deep learning, decision tree classifier (DT), Naïve Bayes (NB) classifier, k-nearest neighbor classifier (KNN) and random forest (RF) classifier can be used for the classification process. The proposed MDP extracts both intensity and edge information and creates the feature vector that increases the classification accuracy during caries detection.

Keywords: Caries, MDP, feature, machine, dental.

ARTICLE INFORMATION

Author(s): A. Sherly Alphonse, S. Vadhana Kumari and P.T.Priyanga

Special Issue Editor: Dr. S. Muthubalaji 

Received: 11/04/2022; **Accepted:** 04/05/2022; **Published:** 13/05/2022;

e-ISSN: 2347-470X;

Paper Id: 0322SI-IJEER-2022-06;

Citation: 10.37391/IJEER.100208

Webpage-link:

<https://ijeer.forexjournal.co.in/archive/volume-10/ijeer-100208.html>

This article belongs to the Special Issue on **Intervention of Electrical, Electronics & Communication Engineering in Sustainable Development**

Publisher's Note: FOREX Publication stays neutral with regard to Jurisdictional claims in Published maps and institutional affiliations.



1. INTRODUCTION

From the daily used applications to the field of robotics the computational intelligence techniques have aided in improving the standards of our life. Computational intelligence techniques are applied so much in the field of robotics. In robotics these techniques help to imitate the human intelligence and become experts in identifying human emotions, pain, gestures and movements etc. [12]. Nowadays, in the field of Orthodontics the computational intelligence techniques make use of handcrafted feature extraction algorithms, segmentation algorithms and machine learning techniques and help an expert in the field of orthodontics to make better predictions. In 1955 John McCarthy framed the term artificial Intelligence. The studies conclude that the Computational intelligence techniques are used in different purposed in Orthodontics. They imitate the accuracy of trained dentists and in some cases, it can be seen that their performance is better than the experts of the field [9, 10, 11]. The numerous data on malocclusions can be fed to the neural network in case of unsupervised learning and the computers predicts the data. The data collected during treatment are fed

into the neural networks. The chosen neural machine learning algorithm makes a needed prediction based on the pattern recognized in the data. These computational intelligence techniques help the doctors and patients in taking better decisions in the field of orthodontics. These computational intelligence techniques should also incorporate the identification of oral diseases to find functional issues during treatments. It achieves a greater specificity and sensitivity in syndrome identification to caries prediction. These computational intelligence techniques assist the orthodontists for better standards of treatments [1].

2. LITERATURE REVIEW

The computational intelligence techniques are utilized in the planning process and therefore optimizing the planning process in orthodontics. The application of the algorithms helps in saving time and increasing accuracy and efficiency. They help the orthodontists to take better and accurate decisions. Big data helps in the gathering of knowledge from various resources that helps in a significant improvement of the accuracy and speed during decision making. Most of the models used were based on neural networks in identifying Cephalometric landmarks, assessing the cervical vertebrae growth and maturation, treatment planning, prediction of orthognathic surgeries, dental images, forecasting the facial appeal and post-orthognathic surgery facial shape [3,4]. More research should be included on incorporating big data to progress learning algorithms and decision-making systems with maximum accuracy.

The deep neural networks with several hidden layers are used to plan the orthodontic treatments. The neural network can also discover the feasibilities of various treatment plans [2,5,6]. Sometimes, there will be drawbacks while collecting data like the missing data. There is an average value method

that achieves better accuracy than the k-nearest neighbours (k-NN) method [13-16]. Therefore, the computational intelligence techniques are a great boon for the naive orthodontists.

The patterns in then radiographs can be analyzed through deep learning and can be classified. Deep learning greatly identifies the hierarchical feature representation and also used for segmentation. The dental caries identification process involves segmentation. Segmentation of has various limitations due to different topologies, particulars of medical structures, and poor illuminations etc. Some of the segmentation methods used in literature are thresholding and connected pixels analysis. Pre-processing is done using the Gaussian blur filter which removes noise and unwanted pixels. Erosion and dilation morphological techniques of image processing can be used for enhancement of images. The Region of Interest (ROI) of the teeth are extracted using connected pixels method. Another method of segmentation is using a level-set method. Also, many features can be extracted using texture statistics methods and by gray-level co-occurrence matrix. These data provide teeth measurements for fully automated dental diagnosis systems. K-means clustering is another method used for segmentation. To achieve high performance during segmentation and classification [14,17-20], various image processing algorithms are also used. Some of the techniques are mathematical morphology, active contour, Fourier transform-based descriptors, contours, texture and edge-based feature descriptors. The image enhancement algorithms are also used before segmentation process and used with handcrafted feature descriptors.

Before using the machine learning algorithms for classification, the features selected and used are of high importance. The features like the “crowding, upper arch” “crowding, lower arch”, “U1-NA”, “ANB”, “overbite”, “lip incompetence”, “curve of Spee”, “nasolabial angle” and “UL-EP” are crucial while taking decisions [16]. A fully-automated cephalometric X ray analysis system with a specialized artificial intelligence technique is implemented in literature. A gold standard obtained from the human experts helps in evaluating the precision of the algorithm used. The computational intelligence techniques have been used in the diagnosis of dental caries. Caries detection in orthodontics is a very much needed process. Computer-aided diagnosis (CAD) method detects caries in dental radiographs. In the 2D images some geometric feature extraction methods are applied and the features are extracted and then applied to some machine learning algorithms for classification. Different feature extraction techniques can also be combined and then the fused features can be used for classification. Different classifiers like support vector machine (SVM), Naïve Bayes (NB), deep learning, decision tree (DT), XG-Boost, k-nearest neighbor (KNN), and random forest (RF) can be used for the classification process [29,30]. Dental radiographs are used for the identification of benign masses, hidden dental structures and cavities. Radiography used a measured burst of X-ray radiation that infiltrates oral structures and then striking the film or sensor [7,8]. Normal teeth look lighter as few radiation infiltrates and then enter the film. Dental caries creates

variations in bone density, and in the film, they seem darker due to higher penetration of X-rays. Dental fillings also appear lighter or darker based upon the density of the material. The convolutional neural network features (faster R-CNN) are used to sense and label teeth in dental periapical films. To improve the recognition accuracy, three post-processing techniques are also used with the R-CNN. A filtering algorithm is used to remove overlapping boxes recognized by faster R-CNN. Then, missing teeth is recognized. A rule-base of teeth numbering system matches the labels of identified teeth boxes. To improve the teeth numbering, postprocessing algorithms are used. Filtering of unnecessary overlapped boxes are also done. An algorithm named non-maximum suppression is used for teeth box recognition. These overlapped boxes with the recognized teeth number are arranged by their probability scores, in which the box having maximum score is reserved and other boxes having an IOU higher than the threshold of 0.6 are removed. However, if the overlapped boxes are with a high IOU, they are not taken into consideration when identified with fluctuating numbers.

Dental radiography is also used to recognize a deceased person, when the other biometric traits are not useful. Here again the segmentation and feature extraction algorithms can be used to extract the features before classification. These features should be invariant to image translation, scaling and rotation to achieve good classification accuracy during the detection of dental caries [25-30]. This paper suggests a novel method of feature extraction that gathers both the texture and edge information of dental caries images.

3. PROPOSED FEATURE EXTRACTION TECHNIQUE USING MAXIMUM DIRECTIONAL PATTERN (MDP)

The overall process involved in a fully automated dental caries diagnosis system is depicted in figure 1. The images are subjected to segmentation and then the feature is extracted and given to a machine learning algorithm for classification. Here in this proposed work a novel Maximum Directional Pattern is proposed for extraction for features that achieves high accuracy when classified using deep learning.

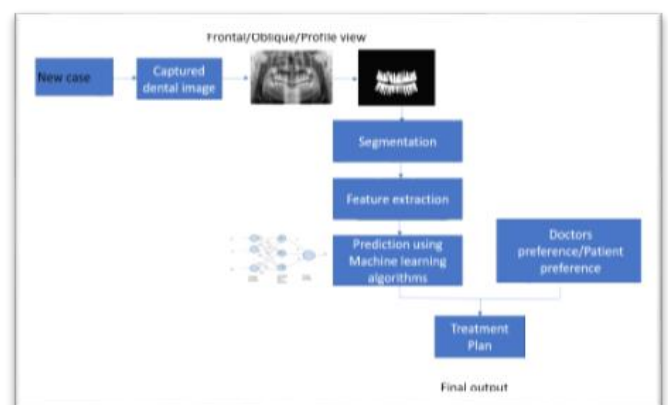


Figure 1: Overall view of a fully automated dental caries diagnosis system

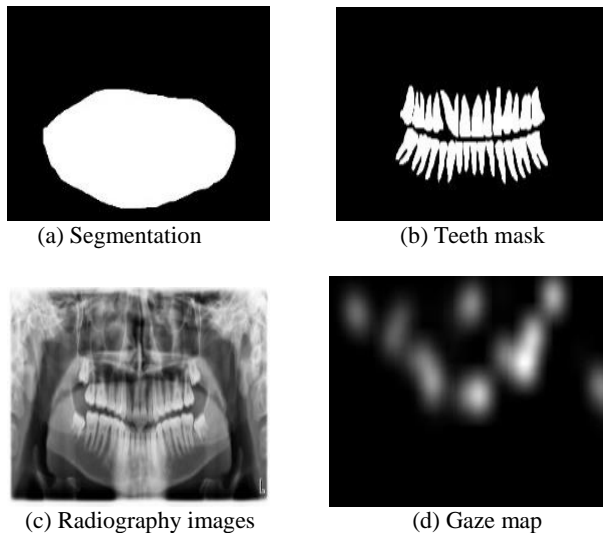


Figure 2: Sample images

The sample images after segmentation, tooth mask, Gaze map and radiography images from are given in figure 2. This proposed feature extraction technique combines both the texture and edge information extracted using Maximum Directional Pattern which helps to improve the classification accuracy. Then the DOG filter applied helps to remove the noise that improves the classification accuracy. The detected images of teeth are given as input to MDP to create the feature vector for the teeth images. The extraction of information is done using MDP and is converted to a feature vector. The edge information is calculated using the directional masks. Then the response images of each mask after convolution with the dental images are obtained.

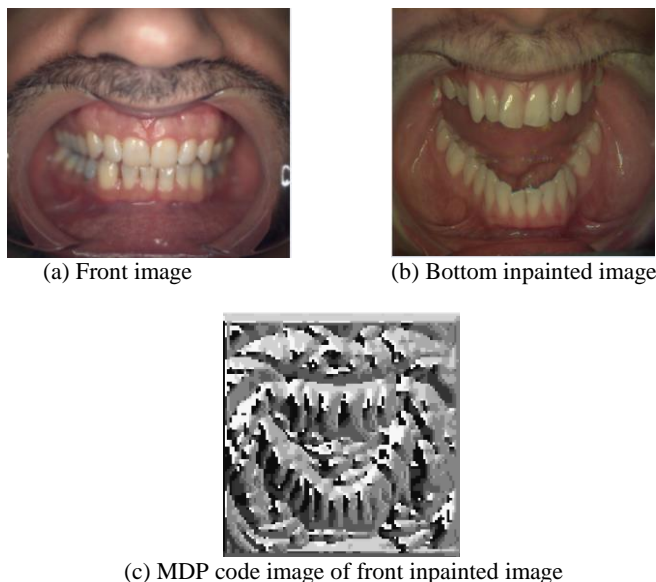


Figure 3: Images before and after applying the MDP

These eight directional Kirsch masks helps in filtering of the teeth edges from the images by convolving the image with Kirsch masks. So, there are totally eight responses for every pixel. From these eight responses choose the maximum

response image. The responses are $\{T_{\theta_0}, T_{\theta_1} \dots T_{\theta_7}\}$. The formula for choosing the maximum response is given as

$$M(x, y) = \max(T_{\theta_i}(a, b) | 0 \leq i \leq 7) \quad (1)$$

Where $T_{\theta_i}(a, b)$ denotes the response gained at exact pixel position (a, b) . Here the eight directional masks are applied and the eight responses are collected for each pixel of the given image. $M(x, y)$ is the maximum among eight responses for each pixel. Then, the DOG filter is applied as

$$D = \text{DOG}((a, b); \sigma_1, \sigma_2) = \frac{1}{2\pi\sigma_1^2} e^{-\frac{a^2+b^2}{2\sigma_1^2}} - \frac{1}{2\pi\sigma_2^2} e^{-\frac{a^2+b^2}{2\sigma_2^2}} \quad (2)$$

Where σ_1 is the standard deviation that should be higher than σ_2 .

$$f(x, y) = M(x, y) * D \quad (3)$$

The convolution of the response images and the DOG filter removes the random noise and aids in sharpening the edges that advances the classification accuracy as in figure 3. Different classification algorithms [21-25] like Bayesian techniques, deep learning, XGBoost, linear models, and support vector machines are used to perform the classification process. Convolutional neural networks (CNNs) are used in many applications like object tracking and identification, safety, armed forces, and biomedical image analysis. These CNNs can also be used in orthodontics to minimize the planning time period of treatment, performing automatic search of landmarks, segmentation of Cone-Beam Computed Tomography (CBCT) images, and identification of defects on X-Ray images. ELM attains good classification performance using Single hidden Layer Feed forward Neural networks (SLFNs) in less time. ELM can classify samples into either two categories or multiple categories [5,8]. There is a random assignment of the weights among the input and the hidden layer. ELM is faster compared to other neural networks because of random assignment of weights. When the dataset is larger the deep learning process achieves high accuracy at lesser amount of time.

4. RESULTS

Here, 300×400 region-of-interest (ROI) image for each image is chosen from the available dental images [9]. First the training set is created using the caries dataset. Label smoothing is the regularization approach used in this multi-class classification tasks. The images are classified as either technical matters, hard tissue and growths, hard tissue subjects, soft tissue, soft tissue subjects, or miscellaneous. Different systems of measurement were arranged to capture dissimilar features of the classification performance of the model, including accuracy, specificity, recall, and precision. The experiments are completed using ten-fold cross validation method and the outcomes are compared. The dental problems are not displayed properly in the radiography and this is a drawback. The edge detection techniques can be used for overcoming the drawback of radiography. Also, Gaussian

filter can be applied on the dental images for smoothing and highlighting the defects. By comparison of pixels from decayed and healthy teeth images the defects can be easily identified. Also, Laplacian edge detection sharpens the edges. Sobel and prewitt operators are also be used for the edge detection in literature. The proposed MDP achieves best accuracy compared to the other edge detection techniques in literature. MDP extracts both intensity and edge information and creates the feature vector that increases the classification accuracy. Also, when Gaussian filter is applied a much clearer image is obtained that improves the accuracy. The histogram obtained using MDP is displayed in figure 4. The code image is divided into grids and the histogram is calculated for each grid.

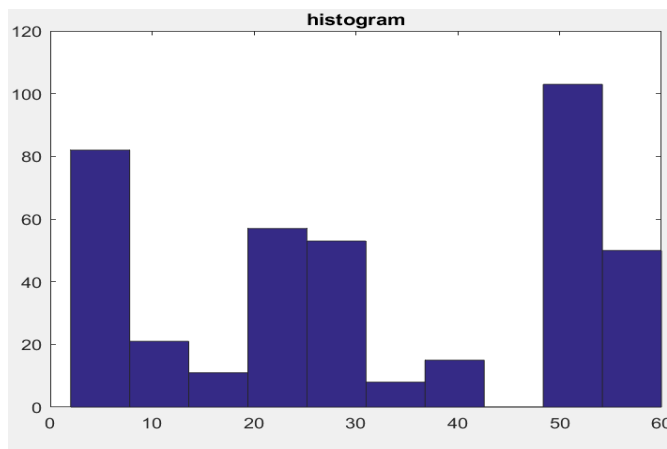


Figure 4: Histogram Obtained from a sample caries image

Table 1 shows the performance of the proposed MDP algorithm compared to the other algorithms in literature. It can be seen that the proposed MDP achieves better results compared to the other algorithms in literature.

Table 1: Performance of the proposed technique for caries detection

Technique	Accuracy (%)	Sensitivity (%)	Specificity (%)	Precision (%)
Canny	89.1	78.0	83.2	88.
Global	90.1	78.5	89.0	88.6
Without edge detection	78.0	68.0	79.5	79.0
Watershed method	88.6	80.2	90.3	90.3
MRIPP [4]	94.5	90.4	88.9	87.6
LDTP [3]	95.4	78.3	96.9	94.3
Proposed MDP	98.6	82.1	100	100

Different types of classification algorithms used in literature are ANN, CNN, SVM, Regression, Random-forest classifier, Bayesian Network, Active shape models, Fuzzy, XGboost, deep learning, Naïve Bayes, spatial spectroscopy and KNN classifiers [27, 28, 29]. Dental radiographs are used for the identification of concealed dental constructions, bone loss, benign masses, and cavities. Radiography used a measured burst of X-ray radiation that infiltrates oral structures and then hitting the film or sensor. Normal teeth look lighter as few radiation infiltrates and then enter the film. Dental caries makes variations in bone density, and in the film, they seem darker due to higher penetration of X-rays. Dental fillings also appear lighter or darker according to the density of the material. Dental radiography is also be used to recognize a dead person, when the other biometric traits are not useful. Novel MDP feature extraction algorithms can be used to extract the features before classification. These features are invariant to image translation, scaling and rotation. In the proposed approach deep learning have been used for classification. Table 2 shows the classification accuracy achieved by different classifiers in caries detection on dental images. The results show that the deep learning approach achieves better accuracy compared to the other machine learning algorithms in literature.

Table 2: Performance of the different classifiers in caries detection

Techniques	Accuracy (%)	Sensitivity (%)	Specificity (%)	Precision (%)	Time in seconds
Regression	78.9	89.0	89.0	89.0	10.0
Random-forest classifier	89.6	87.6	82.0	92.3	11.2
SVM	83.4	84.3	81.0	92.4	10.8
Bayesian Network	90.3	87.0	88.5	93.4	12.3
XGboost	92.3	91.2	83.2	94.3	11.3
Deep learning	98.6	82.1	100	100	16.7

Table 2 shows that the deep learning method achieves better performance when compared to the other classifiers like Bayesian network, XGboost, Random-forest classifier and Regression techniques in literature.

5. CONCLUSION

Computational intelligence techniques are used in our day-to-day life such as smartphones, browsing the internet, online purchasing, using maps, and listening songs etc. The orthodontic practice has been improved significantly by the use of Computational Intelligence techniques. Similar to the process of treatment between a doctor and a patient in this fully automated diagnosis method also the data is fed to the diagnosis system. This diagnosis system uses the machine learning algorithms and the training data for better prediction.

When this diagnosis system and an expert opinion are combined it leads to a better performance. There are many drawbacks in making a fully automated system into practice such as legal issues, and clinical integration issues etc. They must be must be overcome. This diagnosis system monitored by orthodontists can help in combining the field of orthodontics with the digital world. The proposed system using MDP and deep learning achieves best accuracy compared to other techniques in literature.

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