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Detection of Caries in Dental X Ray Images using Multiclass SVM

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Abstract

Caries detection system is important for dental disease diagnosis and treatment. It can be identified using X-ray imaging. The X-ray image contains interest point of dental to get the teeth information according to specific diagnostic intention. The Region of Interest (ROI) includes the caries area on tooth surface. The imaging challenges like noise, intensity in homogeneities and low contrast causes the difficulty for identifying correctly the region of interest in dental images. In this paper, we have proposed an automated caries detection system using texture features and Multiclass SVM (Support Vector Machine) Classifier in dental X-ray images. Initially the X-ray images are pre-processed to remove undesirable noises and other effects. After pre-processing, the image is segmented by K-means clustering method to obtain the region of interest. Texture features are extracted by gray-level co-occurrence matrix and the Multiclass SVM Classifier is used to classify the different types of cavity. The results of proposed method provide the high accuracy and efficiency in the process of getting teeth measurements.

Keywords: Dental x-ray image, pre-processing, K-means segmentation, GLCM feature extraction and Multiclass SVM classifier.

INTRODUCTION

Dental Radiographs are electromagnetic radiated picture of the teeth and mouth. They have large energy for penetration in the body for the image formation on film. Generally on film, air and cavities appear as black; teeth, soft tissue, and fluid appear as different gray shades and enamel and other fillings appear as white [1]. Dental X-ray image show bone loss cavities, hidden dental structures (such as wisdom teeth), which cannot be seen during a visual examination. They are very useful in detecting the early stages of decay between teeth [2]. It is significant to analyse these dental x-ray images in order to improve and quantify medical images for correct diagnosis.

The image processing techniques helps to identify the caries that provide dentists with the precise results of the area affected by the caries [3]. Dental caries are, clearly visible in the x-ray changes and it can be detected from the caries lesion present in the radiographs. Dental caries (cavities), described as "tooth decay", is an infectious disease which damages the structures of teeth. The disease can lead to pain, tooth loss, and infection. Dental caries can be classified in a number of ways depending upon the clinical features, which characterize the particular lesion. Dental caries may be classified according to the location of the individual teeth as pit or fissure caries and smooth surface caries [4].

Dental radiographs are commonly called X-rays. Dentists use radiographs for many reasons: to find hidden dental structures, malignant or benign masses, bone loss, and cavities. A radiographic image is formed by a controlled burst of X-ray radiation which penetrates oral structures at different levels, depending on varying anatomical densities, before striking the film or sensor [5]. A computer aided interpretation and quantification of angular periodontal bone defects on dental radiograph is performed by P.F. Vander Stelt and Wil G.M. Geraets.

MATERIALS AND METHODS

In our proposed system (Figure.1), the following components are included: pre-processing, segmentation, feature extraction and classification. MATLAB is used for implementing the output of the proposed work. Dental X-ray images for different cases were randomly sampled from the atlases and doctors clinics. The input images are obtained from a certified database of ISBI2015 challenge Archive and stored as database [6, 7].

Pre-processing

Image pre-processing is a vital step in the processing of X-ray images due to often poor,uneven exposure and unclear region boundaries (8). The purpose of enhancement of a dental x-ray images is the process of producing an improved quality image, particularly between the different layers of an image. The method of pre-processing needs to be chosen to benefit the other componentsin a system [9, 10].

Image Segmentation

K-means is one of the simplest unsupervised learning algorithms that classify a given data set through a certain number of clusters (assume k clusters) fixed a priori [11]. The main idea is to define k centroids, one for each cluster. These centroids should be placed in a cunning way because of different location causes different result. So, the better choice is to place them as much as possible far away from each other. The next step is to take each point belonging to a given data set and associate it to the nearest centroid. When no point is pending, the first step is completed and an early group age is done. At this point we need to re-calculate k new centroids as centres of the clusters resulting from the previous step. After we have these k new centroids, a new binding has to be done between the same data set points and the nearest new centroid. A loop has been generated. As a result of this loop we may notice that the k centroids change their location step by step until no more changes are done. In other words centroids do not move anymore. Finally, this algorithm aims at minimizing an objective function, in this case a squared error function [12]. The objective function

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \left\| x_i^{(j)} - c_j \right\|^2,$$

Where $\left\| x_i^{(j)} - c_j \right\|^2$ is a chosen distance measure between a data point $x_i^{(j)}$ and the cluster centre c_j, is an indicator of the distance of the n data points from their respective cluster centres.

The algorithm is composed of the following steps:

1. Place K points into the space represented by the objects that are being clustered. These points represent initial group centroids.
2. Assign each object to the group that has the closest centroid.
3. When all objects have been assigned, recalculate the positions of the K centroids.

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.

Feature Extraction

Gray level co-occurrence matrix (GLCM)

GLCM is the method of computing the frequency of pixel pairs having the same gray level in the image. The relationship between the reference pixel and the neighbouring pixels is calculated to determine the textural features of the image(13). For texture characterization, it considers a set of features derived from four directional standardized symmetrical GLCMs: Energy, Entropy, Contrast, Correlation, and Homogeneity. Formulae for computing different GLCM features are given in Table.1 [14].

$$\text{Mean} = \sum_{k=0}^{L-1} r_k . P(r_k)$$

$$STD = \sum_{k=0}^{L-1} (r_k - mean) . P(r_k)$$

A Multi-class SVM Classifier

Classification [15], as it is the last stage of detection works, this involves the process of classifying the given dataset into Enamel caries, Dentinal caries and Pulpal caries. All the features of data images are further classified using Multi-class Support vector machines (Multi-class SVMs). Support vector networks are super-vised learning models with associated learning algorithms that analyse data used for classification and regression analysis [16]. Given a set of training examples, each marked as belonging to one or the other of two categories, SVM training algorithm builds a model that assigns new examples to one category or the other, making it a non-probabilistic binary linear classifier. A Multiclass SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall. A multiclass SVM classifier is utilized for better classification of Dental X-ray images of type Enamel caries, Dentinal caries and Pulpal caries [17].

Results And Discussion

Dental X-ray image database comprises of different type of cavity images. These images are gathered from certified database of ISBI2015 challenge Archive. In the proposed system the dental X-ray images undergo different image processing steps, for example, pre-processing, Edge detection, segmentation and classification. After segmentation, the textural features are extracted using Gray Level Co-occurrence Matrix. The features extracted helps in effective classification of unknown Images. These features are directly given as an input to Multiclass SVM classifier. Two stages are followed to test unknown dental X-ray image sample and classify, the initial step is to segment the image and calculate the GLCM for each input image. The obtained GLCM is utilized to extract features. The second step is to train the extracted features with the desired values of neural networks to decide the dental X-ray image belong to which grade of dental cavity. Multiclass SVM classifier is used for classification. The figure 2 represents an input image of a dental cavity.

Table 1: Formulae for GLCM features

Texture Feature	Formula
Contrast	$\sum_i \sum_j (i-j)^2 P_d(i,j)$
Correlation	$\frac{\sum_i \sum_j (i-\mu_x)(j-\mu_y) P_d(i,j)}{\sigma_x \sigma_y}$
Energy	$\sum_i \sum_j P_d^2(i,j)$
Entropy	$-\sum_i \sum_j P_d(i,j) \log P_d(i,j)$
Homogeneity	$\sum_i \sum_j \frac{P_d(i,j)}{1+\lvert i-j \rvert}$

Table 2: Statistical values of Gray-Level Co-Occurrence Matrix

Image No	Contrast	Correlation	Energy	Entropy	Homogenity
1	0.3712	0.1645	0.9954	0.0459	0.8958
2	0.3654	0.0985	1.0130	0.0695	1.0265
3	0.4211	0.1564	0.9658	0.0687	1.0324
4	0.3854	0.0989	1.0254	0.0543	0.9856
5	0.4135	0.1832	1.0023	0.0594	0.9941

Table 3: Multiclass SVM Classifier Result

Test Image	Standard Deviation	Type of Cavity
Image 1	20.3457	Dentinal Cavity
Image 2	12.5274	Enamel Cavity
Image 3	31.4002	Pulpitis Cavity
Image 4	24.2130	Dentinal Cavity
Image 5	33.1204	Pulpitis Cavity

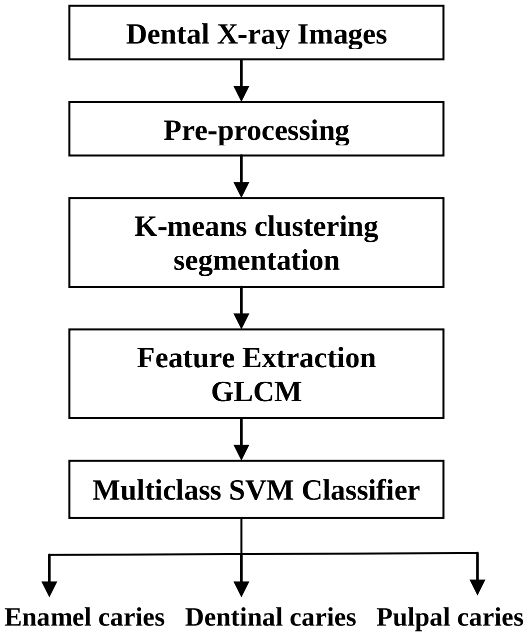

Figure 1: Block diagram of the proposed system

Figure 2. Input Image

Figure 3. Enhanced Image

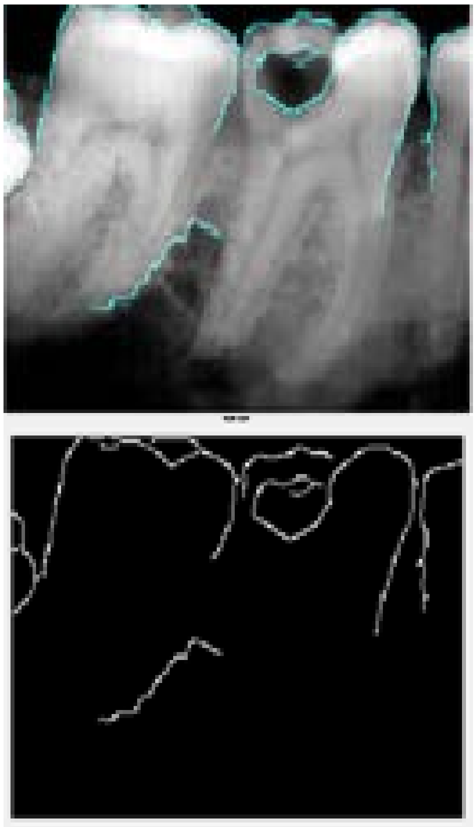

Figure 4. Segmentation and edge detection

Figure 5. Binarization of the dental x-ray image

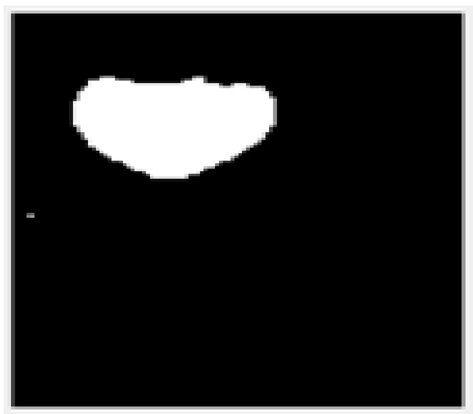

Figure 6. Extracted cavity region

Figure 4.represents the result of the edge-detected and segmented image. Thus the outline of the boundaries of the dental X-ray image and cavity region has been detected. The Figures 5 and 6 shows the resultant of the segmented image showing cavity area and Region of interest (ROI). For accurate detection of Enamel caries, Dentinal caries and Pulpal caries, it is critical to extract a comprehensive set of features. During the feature extraction process, the features of contrast, correlation, energy, homogeneity, entropy and standard deviation are assessed over the region of interest. The features values are then trained in the neural network which is useful in classification phases. The statistical parameters of feature extracted image and feeding to the neural network same result shown in Table.2. However for more accurate classification of different types of cavity, we have applied Multiclass SVM Classifier which gives the output based on standard deviation values.

Table.3 shows the results of caries classification using multiclass SVM and gray level co-occurrence matrix. So by this, the dental X-ray image can be classified as Enamel caries, Dentinal caries and Pulpal caries. The progress shows different epoch, time, performance, gradient, validation checks for different types of caries.

From the inference of the ideology of Edge Detection and Features Extraction for Dental X-Ray [18] Muayad Sadik Croock et al., 2016, we have created our work based on the edge detections and ROI using GLCM techniques for cavity classification rather than using Otsu method used by the above author. Then from the inference of Image processing with a specific focus on identification of caries of Dental X-Ray Image [19] Jufriadif Na`am etal., we have used k-means clustreing for segmentation of dental X-ray images. Then at last by the ideology from [20] Bethanney et al., 2015 Algorithms for the decomposition of gray-scale morphological operation we have used a new method by the combination of edge detections, ROI process for highlighting the cavity and also GLCM and Multiclass SVM classifier techniques for classification of cavity rather than using gray-scale morphological operations.

CONCLUSION

The research work proposes a novel methodology to recognize and grade the severity level of dental cavity from x-ray images. The proposed strategy has been executed utilizing conventional image processing techniques, by performing segmentation, after image enhancement and illustrate contour for teeth to complete the segmentation step. Moreover, we extracted some features of dental x-ray images using texture statistics techniques by gray-level co-occurrence matrix. Extracted data can be performing to get the teeth measurements for dental diagnosis systems. This method is focused on viable classification or diagnosis of dental caries from the dental x-ray images. Based on the features from the cavity region using Multiclass SVM classifier the severity level of dental cavity is classified. Among the features extracted, we considered Standard Deviation as the base to classify the results. The acquired outcomes demonstrate a satisfied accuracy of cavity detection in the proposed technique.

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