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A Brief Review over Dental Image Segmentation and Classification Techniques

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Abstract

Dental image analysis has attained more research interest in recent years due to their flexibility in various applications like human identification, dental disease diagnosis etc. This paper outlines a brief overview about different dental image segmentation techniques. This paper also formulated some details about different types of dental caries. Totally the outlined segmentation approaches are classified as dental image targeted segmentation approaches and the segmentation approaches based on active contour models and thresholding based methods. The shape defining for tooth image is more challenging; most of the approaches are oriented to the shape and intensity levels of dental images. A simple comparison between different approaches is also outlined in this paper.

Keywords; *Dental image segmentation, Dental Caries, Contours, Shape, 3D surfaces.*

I. INTRODUCTION

With the rapid growth in the development of medical radiology imaging from the preceding years, medical image processing has attained a lot of significance in the disease analysis and diagnosis through medical images. Majorly, the medical image processing serves in the image analysis to identify the disease and also the status of disease. As the number of patients increases, the manual effort to be put by doctors increases exponentially. Hence there is a need to design an automatic medical image processing system which reduces the human effort. Medical image processing based diagnosis take care of this responsibility and helps doctors in the proper analysis of medical images. Various medical image oriented applications focused on this aspect design an automatic image analysis system. Recently dental image analysis also gained a lot of research interest in the disease analysis through dental images, due to various dental diseases including dental caries, tooth pathologies, dental abscess, tooth decays etc. Hence there is a need to design an automatic dental image analyzer to diagnose the different types of dental disease properly.

Basically, the automatic dental image analysis system focuses to segment the dental image to make it suitable for further analysis. Earlier approaches put forward towards this issue by developing various techniques based on dental images. However the earlier approaches have their own advantages and disadvantages. These disadvantages include the abnormal exposure, low contrast, and noise [1-3]. Segmentation proceduresuffersfrom some extra issues, such as dental implants, impacted teeth, space between teeth, similarity of body tissues, orthodontic braces, teeth crowding, tooth filling like permanent artifacts and lost tooth which makes the segmentation system more puzzling. Aneffective segmentation technique won't works for all image models and different problems, due to the differences in the image nature and the variations in the problems in each image. Hence there is a need to design a novel and adaptive system which was robust to all types of problems and can provide an

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efficient performance towards the dental image segmentation.

This paper outlines a brief survey over the dental image segmentation approaches. The complete approaches are classified as 2D dental image model based segmentation approaches and 3D dental image based segmentation approaches. The most of the approaches are focused on the shape characteristics of tooth image for segmentation purpose. A brief analysis about the some dental caries is also represented in this paper.

Rest of the paper is organized as follows; Section II outlines some details about different types of dental caries. Section III outlines the complete details of the segmentation techniques and section IV concludes the paper.

II. DENTAL IMAGE ANALYSIS

Dental image analysis is more important to achieve an accurate diagnosis results in the detection of dental diseases. Particularly the detection of dental caries is more important in the dental images which are more prominent in recent days. This section gives the details of different types of cries based on different authors. In earlier, Dr. G. V. Black modeled a classification system to classify various lesions depends on the type of affected tooth (posterior or interior or both) and also the lesion's location (e.g. occlusal, buccal and lingual etc.). According to this model, there are six types of lesions and they are as follows;

Class 1 (C_1): Cavity in fissures or pits over the occlusal surfaces of premolars and molars; lingual and facial molar surfaces; surfaces of lingual maxillary incisors (The class resembles to posterior tooth surfaces which can be seen visually buccal/lingual/occlusal surfaces). Hence the surfaces which are interproximal are not classified as Class 1).

Class 2(C_2): Cavity on the molar and premolar proximal surfaces (This class resembles the posterior tooth surfaces which cannot be seen visually and clinically.)

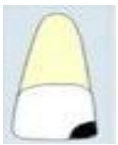
Class 3(3): Cavity on canines and incisors proximal surfaces that do not have an incisal angle involvement (This class resembles the anterior tooth surfaces which cannot be seen visually and clinically)

Class 4(C_4): Cavity on canines and incisors proximal surfaces that have an incisal angle involvement (This class is an extended version of Class 3 which can cover the incisal angle.)

Class 5(C_5): Cavity on the tooth lingual or facial surfaces of the cervical third (Assume the tooth's neck.)

Class 6(C_6): Cavity on the anterior teeth incisal edges and posterior teeth cusp tips (This class resembles the tooth's top surface.)

Table.2 Different types of caries in dental images

Class (C_i)	C_1	C_2	C_3	C_4	C_5	C_6
Sample Figure						

A further classification of dental caries is based on their severity. In such case, the dental caries are categorized as Severe, Moderate, advanced and

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Incipient, contingentto the amount of dentin and enamel complicated in the caries process.

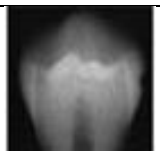
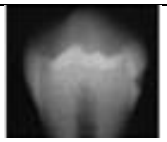
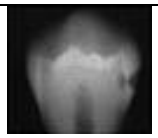
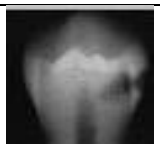
Severe: This class is observed when the lesion is extended through enamel through dentin and passes to more than the half distance of pulp.

Moderate: This class is observed when the lesion is extended more than halfway distance into enamel but not passed into the dention-enamel junction (DEJ).

Advanced: This class is observed when the lesion is extended through or to the DEJ but doesnot passes more than halfway into the pulp.

Incipient: This class is observed when the lesion is extended less than the halfway through the enamel.

Table.3 Different types of caries according to their severity

Class	Figure	Sample Radiograph
Incipient		
Moderate		
Advanced		
Severe		

III. LITERATURE SURVEY

In earlier there are so may approaches were proposed to perform the dental image segmentation task. The detailed literature survey over the earlier developed dental image segmentation techniques are illustrated in this section.

A. General Segmentation methods

Numerous general image segmentation approaches proposed in computer graphics. Some of the algorithms include random walk [5], fitting primitives [7], clustering [4], shape diameter function [6] and fast marching watershed algorithm [8]. Katz etal.,[4] developed a novel “hierarchical mesh decomposition algorithm” to decompose the dental image into segments based on the mesh which generally refers to the region segmentation at the deep concavities. The main advantage of this approach is it avoids the over segmentation between the jaggy boundaries between the components. However, all these methods aimed at segmentation of regions based on different similarity measures. But the shape defining for tooth image is more challenging and further these approaches are not directly applicable to dental images.

B. Segmentation trough active contour models

Based on the different characteristics of dental images, various approaches are proposed to achieve efficient segmentation regions from the dental images. Most of the approaches are focused on the shape of dental image. Under this constraint, the curvature shape of the dental image is mostly considered and different curvature based segmentation approaches developed.

Jain and chen [9] proposed a dental image segmentation model based on the “active contour model (ACM)” [10] through the first energy function by which the active contours can be extracted repetitively. Basically the ACM models are based on the iterative manner in which the convergence time is more and also difficult to design the functions accomplished through geometric region information.

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Zoroofic and Momeni [11] developed a tooth segmentation approach based on the level set and projection/resampling of panoramic dental images. It is an automatic classification technique through a multi-step approach. Initially this approach generates a 2D panoramic image from the computed tomography (CT) image and then the individual teeth are separated through the vertical lines. Further the upper and lower teeth are separated through the horizontal lines. But some teeth like molar teeth cannot be segmented properly through this rectangular region based segmentation because they are not aligned vertically.

Chae and Gao [12] proposed a new teeth segmentation technique based on the space along the arch of jaw. This technique helps in finding the adjacent tooth by measuring the plane of teeth separation that have the maximum "average intensity value (AVI)" based on the orientation and position of teeth separation plane. However this method cannot extract the teeth region which was penetrated into the soft pulp which has lesser intensity values. Further two more methods are developed to segment the teeth region or its axis through semiautomatic methods.

Chae and Gao [13] introduced a semiautomatic teeth segmentation technique through the level set (LS)based segmentation. This approach considers the intensity and shape as main attributes of the teeth, which regulates the expanding or shrinking power of the function of LS. Further some more segmentation techniques are proposed based on this intensity and shape of teeth image to separate its crown and root. Though this approach achieves an efficient crown region with minimum error, it needs a manual extraction of contour around the tooth which takes an extra 5min time for every tooth.

Galaniset.al,[14] developed a dental implant axis detection technique based on the Square Regression Line Fitting (SRLF). This method tries to find the least SRLF, the bone centroids and the prosthetics of every slice. Further this method also extracts density and geometric scatterings of bone and prosthetic around the axis of implant. This approach requires a manual marking of the required regions needs to be segmented around each and every tooth. Moreover, the segmented region of tooth comprises the tooth as well as the cortical jawbone, so the axis of the tooth cannot be extracted accurately. So many approaches are developed in further to solve this issue by considering the "support vector machine (SVM)" [15] and "principal component analysis (PCA)", which focuses the features and are trained to segment the image. These approaches requires additional information, and also are based on the level set method which results in the high computational time associated to the segmentation methods based on the thresholding and the methods based on the growing of seeded region.

Further the main complexity is at the determination of teeth regions from the sockets because the brightness of both regions and the teeth boundary gradient are similar and indistinct. Several earlier methods accomplished the pixel intensity and didn't focus on the histogram threshold determination of dental CT images to determine the bones and tissues. Hence the automatic tooth segmentation techniques based on these aspects are very complexity which introduces an unnecessary computational burden over the system.

C. Segmentation through thresholding

Depends upon the methodology accomplished for segmentation of dental images, the earlier approaches are broadly classified as Region Based Segmentation Methods, Threshold Based Segmentation Methods, Cluster Based Segmentation methods and Boundary based segmentation methods. The main objective of these methods is to segment the image into regions, with the help of discontinuities in the image pixel intensities [16], [17]. The aim of study in [16] and [17] was to segment panoramic X-ray images of teeth to help the dentist in the process for osteoporosis and osteopenia. Further the segmentation method

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proposed by Modi and Desai [17] is based on the region growing and accomplished over bitewing X-ray images. The main drawback of this method is how to determine the significant coefficient for segmenting the regions. Furthermore, it works only if pre-defined functions of curves were given [18].

The further class is of threshold based and most of the authors focused on this mechanism only due to its simplicity and ease of accomplishment. In these approaches, the pixels are classified into respective regions based on a pre-determined value of threshold. The pixels that have an intensity values greater than the threshold are considered as one region and the pixels those have less than the threshold are considered as other region. Otsu is one of the typical thresholding methods and discovered by Otsu in 1975 [19]. Based on the Otsu thresholding, a new dental image segmentation mechanism is proposed by Lin et. al., [20] which was accomplished in four stages namely, adaptive power transform based "image enhancement, Holder Exponent based local singularity analysis [22], Otsu thresholding oriented tooth recognition and Connected component analysis (CCA)". Finally the tooth delineation is done using the snake boundary tracking and morphological operations. Ajaz, A. and Kathirvelu [21] developed a new dental image segmentation framework based on thresholding followed by some mathematical morphological operations. This approach tried to segment the dental regions such as Crowns, Fillings, and Bridge.

A dental code is generated based on the distance between the works and the angle at which the dental works are aligned.Amer, Y. Y. and Aqel, M. J [23] proposed an effective segmentation method on panoramic image to segment the wisdom tooth. Tikheet. al., [24] proposed to detect the enamel carried in interproximal caries through the dental image segmentation. Initially this approach rotated the image and next, the histogram analysis is accomplished to study the intensity level of caries. Next, tooth area is separated through image segmentation and finally the obtained area is processed for identification. Indrswaiet. al., [25] proposed a system for teeth segmentation using "Decimation-Free Directional Filter Bank Thresholding (DDFBT)" and "Multistage Adaptive Thresholding (MAT)". This system was built in three phases, which are formation of horizontal and vertical directional images though DDFBT, noise removal and teeth edge enhancement through the enhancement of directional images and Segmentation through MAT with Sauvola Local Thresholding [26]. Compared a single threshold, multiple threshold will optimize the segmentation performance. Based on this strategy, M. Razaliet. al., [27] proposed to derive three threshold based mean, median and Otsu for dental image segmentation. From the results, they observed that the medina threshold has better results compared to mean and Otsu Thresholds. In the region segmentation performance, the median threshold is observed to cover more teeth area compared to the remaining thresholds. Further some more approaches are proposed based on Histogram Thresholding [28] and Local Variable Thresholding [29, 30].

The further class is cluster based segmentation. Clustering a method which is used to make the alignment of data automatically based on certain similarity degree between the image data. The methodology of clustering depends on the input data and also on the application. The number of groups/clusters to be formulated is the ne which has to give as an input to the clustering system. Only limited work is accomplished towards this class over dental images. Alsmadi [31] developed a new effective and fully automatic segmentation approach for the segmentation of jaw lesions in X-ray panoramic images. A "Hybrid Fuzzy C-means and Neutrosophic approach" [32] is accomplished here for the purposed of segmentation of jaw lesions. Further, Son and Tuan [33] proposed a new co-operative framework that is based on "Semi-supervised Fuzzy Clustering" for dental image

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segmentation. Here the Otsu thresholding is accomplished for the removal of background from an X-ray dental image. Then the FCM [34] algorithm is applied to get Dental Structures and finally semi-supervised entropy regularized FCM is applied to improve the segmentation results.

The final class of segmentation is based on the boundaries of images. These approaches focused to extract the edge wise and pint wise discontinuities in the grey levels of image. Senthilkumaran [35] proposed a method of edge detection using Genetic algorithm for Dental X-ray images edge detection. GA is flexible for edge detection is shadow segments. L. Grafova [36] proposed a new approach based on the statistical analysis for the detection of edges. Initially a set of edges are detected from an input image and then the consistent maps are built from detected edge results. Then the probabilities and average probabilities are evaluated and then an overall correspondence is measured for each correspondence and finally the correspondence map providing best overall correspondence is considered as final result. A more recentapproach on boundary-based segmentation is known as "active contour model" [37-39], also called snakes,in which the segmentation is done by the delineation of boundary of image. In these models, the main objective is to minimize the energy initialization functions and the stopcriterion is when the minimum energy is detected. Finally, the perimeter of an object is extracted based on the minimum energy value.

Table.1 Comparison between different dental image segmentation techniques

Ref.No	Methods used	Disadvantages	Year
[9]	1. active contour model (ACM) for contour extraction of every tooth	1. Slow convergence 2. difficult to design the functions accomplishing geometric region's information	2004
[11]	1. Level set method 2. Projection/ resampling of panoramic images	1. Molar types teeth cannot be extracted accurately	2008
[12]	1. Considered the space along the jaw arch. 2. Maximum intensity level	1. Not able to extract the region penetrated into the soft pulp. 2. High computational time	2008
[13]	1. Semiautomatic 2. Level set method	1. Requires manual input to represent the region which has to segment.	2010
[14]	1. SRLF 2. Centroids, prosthetics of every slice are extracted	1. Requires a manual marking of the required regions needs to be segmented around each and every tooth	2007
[18]	1. Applied mathematical morphology for teeth segmentation. 2. Grayscale contrast stretching algorithm for enhancement.	1. Not robust to multiple classes in the dental images.	2006
[30]	1. Teeth ROIs are extracted based on integral projection and Iterative thresholding.	Binary Linear SVM classifies only two classes. In the case of more than two classes, need an addition SVM,	2010

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	2. A binary linear SVM using the Crown size, skew-adjusted relative length/width ratios of both teeth and pulpsas features.	results in additional cost.	
[28]	1. Histogram equalization is used for enhancement. 2. used color features to identify dental images	1. Over enhancement due to the histogram equalization	2012
[35]	1. Edges are detected through Genetic algorithm.	1. Higher convergence time for genetic algorithm. 2. No Separate method for segmentation.	2012
[22]	1. Adaptive power law transformation is used to reduce contrast variations. 2. Holder exponent is used for structure extraction along with Otsu thresholding.	1. Complex computation and more processing time are main disadvantages of Otsu thresholding.	2013
[25]	1. Horizontal and Vertical directional images formation through DDFBT. 2. Segmentation using MAT with Sauvola Local Thresholding	1. DDFBT results in more number of bands, resulting in more computational complexity.	2015
[26]	1. Semi-supervised FCM is accomplished for segmentation 2. Otsu thresholding is used for background removal.	1. Complex computation and more processing time are main disadvantages of Otsu thresholding.	2016
[31]	1. Hybrid FCM algorithm 2. Neutrosophic method	1. higher FPR due to the imbalance between the grey levels of jaw lesions and background	2018
[33]	1. Combined the FCM with Otsu thresholding and semi-supervised learning	1. more complex	2016
[37]	1. chan-vese method to detect the objects in dental images 2. Applied on GPU and checked for speed of segmentation process	1. Chan-vese method is simple and effective but have limited performance in dental like images which have a minor variations in the grey-level pixel intensities.	2015

IV. CONCLUSION

Dental image segmentation is more important to understand different types of dental disease more accurately. This paper outlines a brief survey over different dental image segmentation approaches based on 2D image mode and 3D image model. But the shape defining for tooth image is more challenging and further the general segmentation techniques such as random walk, clustering etc. approaches are not directly applicable to dental

images. The 2D image model based segmentation approaches considers the images directly to perform segmentation whereas the 3D image based model first tires to construct the image based on characteristics of image and then they will perform segmentation. The common disadvantage of 2D approaches is less accuracy and the computational overhead is of the 3D based approaches.

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