Proc. of the Intl. Conf. on Advances in Computing and Information Technology-- ACIT 2014

ISBN: 978-981-07-8859-9

Dental Age Assessment for Forensic Identification Using OTSU and Watershed Algorithm

Muhamad Rizal Mohamed Razali[a] , Nazatul Sabariah Ahmad[b], Waidah Ismail[c]

***Abstract*— Dental forensic or forensic odontology had played an important key in identification of person involved in the disaster, criminal crime and ethnic identification. The investigator will get the needed information from the tooth prints, radiograph, rugoscopy, cheiloscopy, molecular methods and photographic study. X ray image is one of the aid in the investigation, as the investigator can retrieve the information from the x-ray of the victim. In this paper we present a method to segment the premolar teeth from the x- ray image using OTSU and watershed algorithm. Data were collected from Faculty of Dentistry, Universiti Sains Islam Malaysia (USIM). The target area of segmentation is premolar teeth for the early tooth development stage (TDS).The methods we used were OTSU and watershed algorithm.**

Keywords—Otsu, Watershed model, Tooth Development Stages

I. Introduction

Dental age assessment has an important role in forensic, pediatric and orthodontic treatment planning [1]. Dentists used Demirjian's method to determine the age of the children based on the dental maturation scale [2]. Dental age was estimated, using the left mandibular teeth except the third molar rated on 8-stage scale from A to H, according to Demirjian's method[3]. Currently the process of classification of the teeth is carried out manually, based on the radiographic image and visual assessment. The collaboration of researchers from computer science and dentistry has given an opportunity to create an automated system for tooth development assessment. Image processing techniques are widely used in medical environment especially in helping the doctor to make a decision, improving patient care and allowing a better understanding of the effect of treatments on various diseases. There are lots of issues in segmentation on the x-ray images which are inconsistent due to x- ray absorption, noise and uneven distribution of intensity [4].

Muhammad Rizal Mohammad Razali
Penang Skills Development Centre, Bayan Baru
Pulau Pinang, Malaysia

Nazatul Sabariah Ahmad
Faculty of Dentistry, Level 15, Menara B, MPAJ Pandan Indah, 55100
Kuala Lumpur, Malaysia

Waidah Ismail *(Coressponding Author)*
Faculty Science and Technology, USIM, Bandar Baru Nilai, 71800
Negeri Sembilan, Malaysia

The goals of this research are to apply segmentation methods on the tooth x-ray images to segment the premolar teeth as initial study and apply to all 14 teeth as illustrated in Demirjian's method. Methods of the segmentation that are discussed in this paper were OTSU threshold and watershed model. At the same time, the estimated execution time for each method will be determined.

II. Literature Review

A. *Demirjian Method*

Demirjian method was first introduced in 1973, presented a dental age assessment method based on the stage of tooth development assessed in panoramic radiograph[2,5]. Panoramic radiographs were used because they are easier to make than intraoral radiographs in young or nervous children. It is designed primarily for use by clinicians who want to know if the dental maturity of individual deviates from the norm, because the score is calculated as a function of age and the predictive interval is given for the maturity score. Based on this method, the study is focused to segment the lower left first premolar tooth. Demirjian method groups the teeth into 4 types which are incisors, canines, premolars and molars. The dentist will assign the rating for each tooth A to H based on the developmental stages of the permanent dentition Fig 1.

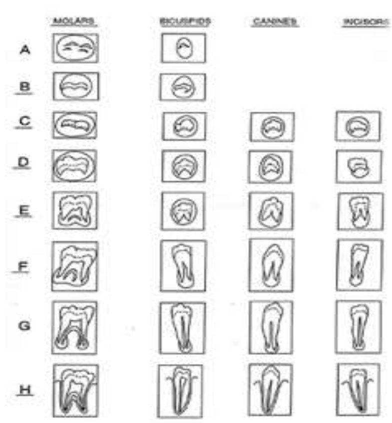

Fig 1. A to H development stages teeth Using Dermirjan [2]

B. *Segmentation*

Computer vision segmentation is a process of dividing a digital image into multiple segments. Image segmentation

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usually used to determine the line, curve and boundaries of the object. Pixel based segmentation refers to each pixel is segmented based on the grey-level values, example of pixel based segmentation is a threshold. Edge based segmentation will detect and links edge pixel to form a contour. The edge based segmentation method normally used to avoid a bias in the area or size of the segmentation without using a complex threshold method. The fact of Edge-based segmentation is the position of an edge is given by an extreme of the first-order derivative or a zero crossing in the second-order derivative [6]. Region-based segmentation methods attempt to partition or group of connected pixels with similar properties [7]. These image properties consist of

i. The Intensity values of the original images, or computed values based on an image operator
ii. The unique Textures or patterns for each type of the region
iii. Spectral properties that provide multidimensional image data

In this paper we focused on region based segmentation because of the advantages such as region segmentation cover more pixels then edge approach. Region technique is generally better in noisy images where the edge is difficult to detect [8].

C. *OTSU*

The Otsu method is invented by Nobuyuki Otsu. In image processing, Otsu's thresholding method (1979) is used for automatic binarisation level decision, based on the shape of the histogram[9]. The algorithm assumes that the image is composed of two basic classes: Foreground and Background. It then computes an optimal threshold value that minimizes the weighted within class variances of these two classes. It is mathematically proven that minimizing the within class variance is same as maximizing the between class variance. Otsu method has been used in Waidah et al (2011) paper in automated detection of leukaemia cells[10], Jun Zhang and Jinglu Hu et al (2008) has highlighted OTSU method in their paper Image Segmentation based on 2D OTSU method with histogram analysis[11]. The process to generate the automated markers involved threshold. Here use *I* is a binary image Let *I*(*x,y*) be the coordinates of each pixel in an image. Threshold method assumes two classes, C_0 and C_1 (background and foreground respectively). The threshold *T*, allowing the best separation of classes in grey levels, would be the best threshold [12].

$$I(x,y) = \begin{cases} 1, \text{if } I(x,y) \geq T \\ 0, \text{Otherwise} \end{cases} \quad \text{Eq1}$$

The pixels of the *I* coordinate will be changed to white (1) if the intensity of the pixel more than equal threshold value, otherwise it will be black (0) Eq(1). Thresholding is a method of segmentation, which is defined as partitioning an image into homogeneous region. The simplest property that pixel in a region can share is intensity. The disadvantage of the threshold is that only considers the intensity of pixels and ignoring any relationship between them. There is no guarantee that the pixels identify by the thresholding process are contiguous. It may include extraneous pixels that are not part of the desired region and at the same time miss isolated pixels within the region (especially near the boundaries of the region). These effects get worse as the noise gets worse, simply because it's more likely that a pixel's intensity does not represent the normal intensity in the region. When thresholding is used, typically have to play with the threshold value, sometimes the result will not fully segment the region and sometimes getting many extraneous background pixels. [13]

D. *Watershed Segmentation*

Watershed algorithm invented by F. Mayer in the early 1990. The algorithm converts lines in an image into "mountains" and uniform regions into "valleys" that can be used to help segment the objects[14]. The watershed algorithm needs to have markers to mark the regions, based on the markers the algorithm finds the lowest pixel values to form valleys and find the highest pixel values to form mountains. The algorithm successively floods the image from the lowest to the highest point; if the flooded regions merge across with the mark regions then the algorithm will segmented the regions.

E. *Dental Image Recognition*

X-rays are among the oldest sources of electron microscopy radiation used for imaging. X-ray images are generated simply by placing the patient between an x-ray source and a film sensitive to x-ray energy. EyadHaj mentioned in the forensic identification, law enforcement agencies have been exploiting biometric as identifier where behavior characteristics (e.g. speech) are not suitable for post mortem identification. Therefore a postmortem biometric identifier has to survive such severe conditions and resists early decalcification that affects body tissues where dental features are considered as the best candidates for postmortem identification (EyadHaj *et al* 2006)[15]. K.W. Hussein et al. (2009) has highlighted the variations in tooth size and their on arch dimension are found in Malay school children[16]. There are few papers highlighted on the dental image recognition but none on the image recognition for the early dental age assessment. The techniques for the dental X-Ray Image segmentation have done by EyadHaj et al. (2006) using grayscale stretching and morphological filtering algorithms. The growth of technologies and important needs in dental forensic, lead researchers focused on the teeth segmentation

III. Data Collection

The X ray images are collected from Faculty of Dentistry, Universiti Sains Islam Malaysia (USIM). The X ray images format is in JPEG and the dimension of the images is 2077

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pixels width and 857 pixels height. Focused of the research is dental age assessment from the radiograph images.

IV. Method

We performed three testing which are single marker, multiple marker and auto marker show in Fig 2. Marker is important in watershed algorithm; from the marker it will determine the basin and the maximum region. Watershed algorithm requires values of *mountain* and *basin* to begin the segmentation process. In order to generate automated markers (*mountain and basin)* from original image there are steps using OTSU, Dilation, Erosion and Watershed. Process of segmentation involved a threshold process, from the RGB image we need to convert to 8 bits greyscale image. T value in OTSU threshold is set to 100 based on the threshold notation if the coordinate value more than T value it will become white and the value less than T it will become black. After applying OTSU to generate the maximum value, need to apply dilation process then continue with the erosion process to get the minimum value. Based on the maximum and minimum value watershed algorithm will determine the region of the segmentation. The following section describes the analysis of the segmentation for the premolar teeth.

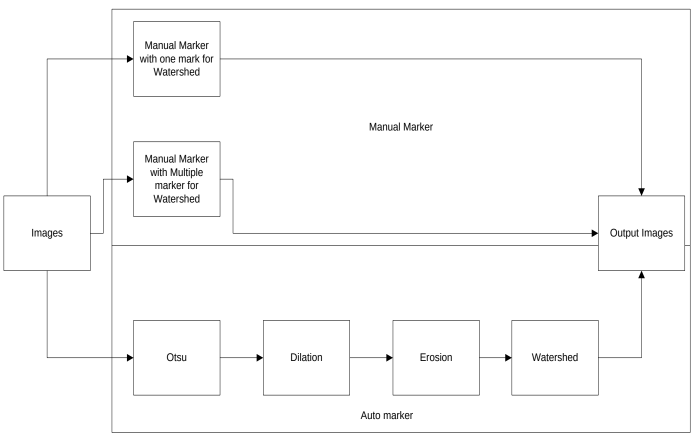

Fig 2: Flowchart for the manual and auto marker

V. Analysis

The analysis is carried out from the 20 sets of the real x-ray images. The analysis based on the manual marker included single marker and multiple markers, automated markers

A. *Manual Single Marker*

The experiment for the watershed single marker has been done by marked the lower left premolar tooth as show in the Fig 3 is the example of one marker. Fig 4 is the result from single marker which there is no segmentation done.

Fig 3:Manual single marker

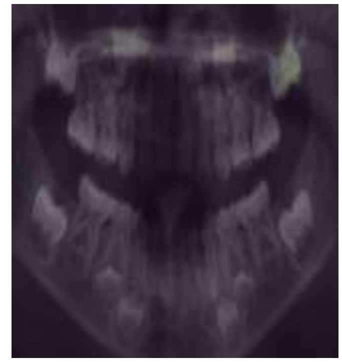

Fig 4: Watershed result with single marker

B. *Manual Multiple Markers*

The experiment for the watershed single marker has been done by marked the lower left premolar tooth as show in the Fig 5 is the example of one marker. Fig 6 is the result from single marker.

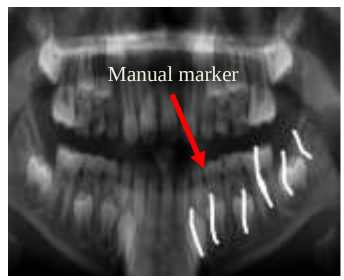

Fig 5: Manual multiple markers based on Dirmirjian method

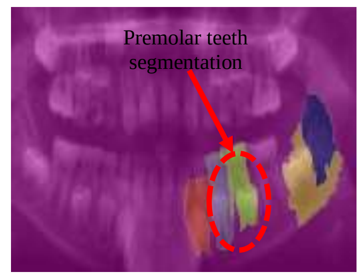

Fig 6: premolar segmentation using manual multiple markers

C. *Automated Markers*

Multiple markers watershed give a positive result, the next step of the experiment is to enhance the manual marker to automate. The process to generate the automated markers involve OTSU threshold the next step is dilation to generate the maximum value and erosion to generate minimum value Fig 7 .The erosion value set to 8 which mean if the pixel value less than 8 it will group together to generate the basin and the dilation value set to 4 which mean if the pixel after erosion the value more than 4 are grouped together to generate the maximum value. After getting the minimum and maximum point the next step proceed to watershed algorithm Fig 8 show the result of automated markers watershed.

Fig 7. Automated marker

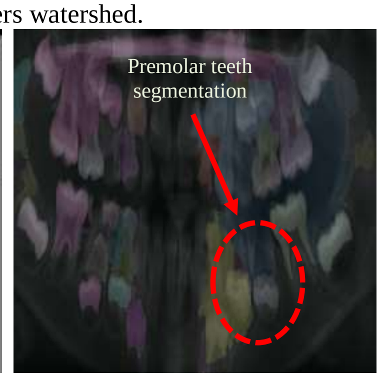

Fig 8. Premolar teeth segmentation using watershed

ISBN: 978-981-07-8859-9

VI. Result

This paper gave two results which are Watershed topology and time execution for the images. The time of the segmentation is tested in the experiments, in Table 1 shown the estimation time of execution for each method, based on the table OTSU method take less time compared with manual markers and automated markers watershed.

Table 1: Estimation executions time for each method

Image	OTSU(ms)	Manual Multiple Markers (ms)	Automated Markers (ms)
1	4.826	90.728	31.979
2	4.658	86.207	24.248
3	5.693	82.412	54.929
4	4.714	97.092	24.983
5	4.650	87.656	20.338
6	4.738	79.337	20.828
7	4.657	86.422	21.491
8	5.749	80.175	51.817
9	5.698	85.616	50.573
10	5.747	81.473	55.186
11	5.751	80.144	55.447
12	4.640	85.830	26.406
13	5.067	89.358	26.537
14	4.641	83. 228	24.568
15	4.647	88.015	28.099
16	5.711	84.822	50.195
17	5.702	83.549	55.668
18	5.769	86.503	57.308
19	5.655	85.873	56.469
20	4.606	94.057	22.573

The result shows as in Table 2, a Watershed algorithm with single markers produced a negative result which is 0%, although multiple markers watershed gives a positive result but the user needs to mark the tooth manually. Multiple markers watershed give better result if we compare with single marker, because in multiple markers, it will generate a range of minimum and maximum values, from the range of minimum values watershed algorithm will choose the lowest point as a basin and the maximum point as a mountain. Automated markers watershed able to detect and segmented 92.5% of the premolar teeth from the 20 images, table 2 shown the percentage of premolar teeth segmentation using automated marker watershed. The result of the experiment, from the 20 images tested, watershed algorithm able to segment 97.5% the premolar teeth for every image, even the segmentation area has not fully covered the area of premolar teeth.

Table 2: Percentage comparison between manual markers and automated markers

Manual single Marker	Manual multiple Markers	Automated markers
0%	97.5%	92.5%

VII. Future Research

The second phase of this research is to enhance the region by applying Cellular Automata to remove unwanted area and modify the watershed algorithm so that it can segment the tooth based on Demirjian method requirements.

VIII. Conclusion

All the methods tested able to segment the premolar teeth but not in fully shape of the teeth. Watershed manual marker need to mark more than one tooth in order to get a consistent result. The time of execution to segment the premolar teeth, OTSU method is the fastest if compare with watershed automated marker and watershed manual marker. The regions of the segmentation need to enhance by applying cellular automata and modify the watershed algorithm.

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About Author (s):

I have 12 years experience as a lecturer , currently I am futher my studies in PhD at University of Islamic Science Malaysia USIM, Master In Information Technology, from the University Technology of MARA in 2005 . Area of interest is in computer image processing.

Dr. Nazatul obtained her 1st degree from UKM in dentistry DDS (UKM) in 2004. She then further her studies in Doctor in Dentistry in Paediatric Dentistry from Eastman Dental Institute London (DDENT Paed Dent). She had practiced as general dentist in Ministry of health for 3.5 years and has experience as a lecturer for 6 years in USIM. She is now a Lecturer and Specialist in Paediatric Dentistry and her main research interests are dental development timing and forensic.

I have experience as lecturer for 8 years. I am graduated my Bsc(Hons) in University Liverpool, UK, Master in University Technology Mara, Malaysia and PhD in Information System and Computing from Brunel University, UK. My area of interest on medical domain.