Orthopantomographs Fuzzy Segmentation for Malaysian Children Automatic Age Assessment

Waidah Ismail, Seyed Mostafa Mousavi Kahaki, Md Jan Nordin, and Nazatul S. Ahmad

***Abstract*—Image segmentation plays an important and incisive role in many medical image analysis applications. Automating this process with high accuracy can increase the medical applications performance significantly. There are plenty number of segmentation techniques have been proposed during the last decades, however, these methods still suffer from a high error rate especially in Orthopantomographs. A Fuzzy based segmentation has been developed in this study to improve the performance of the Malaysian children age assessment. The proposed method is based on the distance of the local mean to the Fuzzy response of the image to extract the segmentation result. The proposed technique has been evaluated using standard image dataset including X-Ray images of 456 patients collected from Malaysian children aged 1 to 17 years old from the collection stored at the department of the dentistry research at Universiti Sains Islam Malaysia. The results indicate that the proposed segmentation technique can successfully perform the age assessment.**

***Keywords*— Automatic Age Assessment, Image Segmentation, X-ray Imagery, Classification, Feature Extraction.**

I. Introduction

Dental age assessment has an important role in dentistry, orthodontic and forensic. Dental features are regarded as the best form for postmortem biometric identification. Tooth structure survived most events in disaster, accidents and violent crimes, where bodies can be disfigured to such extent that identification by family member is not possible [1]. In recognizing tooth structure, individual with numerous and complex dental treatment are easier to identify. This is true in adult. But in children, stage of tooth development can determine the age. Developing permanent teeth can be seen and assessed using an orthopantomographs.

Dental X-ray varies from good to poor quality. Manual assessment requires high skill and training and the outcome may have wide variation between assessors. It becomes important to develop automatic dental identification systems using segmentation technique and referring to dental features such as shapes of root and crowns. Reliable identification of humans is important for many applications, such as law enforcement, border control, homeland security and airport security. Dental features are regarded as the best candidates for postmortem (PM) biometric identification. Essential properties for any digital imaging system should include the following: (a) the image produced is of diagnostic quality; (b) the radiation dose is equal or reduced compared to film; (c) that digital radiology techniques are compatible with conventional x-ray generators; (d) that lossless archiving is allowed in an image file format that promotes interoperability within the DICOM standard; and (e) the time required for the total procedure should be equal to or less that the film [2]. In identification of the teeth Hausdorff distance was used in measuring between the teeth contours [1]. Fuzzy approach was used in the level crossings in the proposed video-surveillance system to prevent accidents in safety-transport applications [3]. Tuan [4] propose a new cooperative scheme that applies semi-supervised fuzzy clustering algorithms to dental X-ray image. The Otsu method is used to remove the background area from X-ray dental image. Then, the fuzzy clustering algorithm (FCM) is chosen to remove the dental structure area from the results of the previous steps. Finally, semi-supervised entropy regularized Fuzzy clustering algorithm (eSFCM) is applied to clarify and improve the results based on the optimal result from the previous clustering method. In the paper [5], the author divides a dental X-Ray image into some segments and identified equivalent diseases by classification method called Affinity Propagation Clustering (APC+). Tooth segmentation can be done using computer-aided orthodontics. Wu, et al. [6], proposed a novel tooth segmentation approach based on morphologic skeleton for scanned dental meshes. The skeleton describes the topological relationship among different dental parts on meshes and is exploited by automatic adjacent teeth separation. In dental X-ray image segmentation, Rad, et al. [7] use the level set method for doing boundary-based segmentation. This method detects edges and angles and other image characteristics on surface which is covered by a curve. However, in their research [7], they found that, choosing an appropriate function that represents the curve is a big issue and still many research have to be done to answer the question. In the paper Li and Wang [8], by using segmentation based solved by a linear system defined by a discrete Laplace-Beltrami operator with Dirichlet boundary conditions. A set of contour lines are sampled from the smooth scalar field, and candidate cutting boundaries can be detected from concave regions with large variation of field data. The algorithms are focusing in the crowding problems.

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II. Automatic Age Assessment Method

As presented in the introduction section, dental age assessment is important in different fields such as dentistry, orthodontic and forensic. Automating this process can help us to improve the accuracy and speed of this process. We developed a new method of automatic age assessment Based on the available dataset images which provided by the department of dentistry research at the University Sains Islam Malaysia from children aged 1-17 years old. We improve the performance of our pervious study [9] by improving the image segmentation part using distance based fuzzy method. The visual framework of the automatic age assessment technique is presented in Fig. 1.

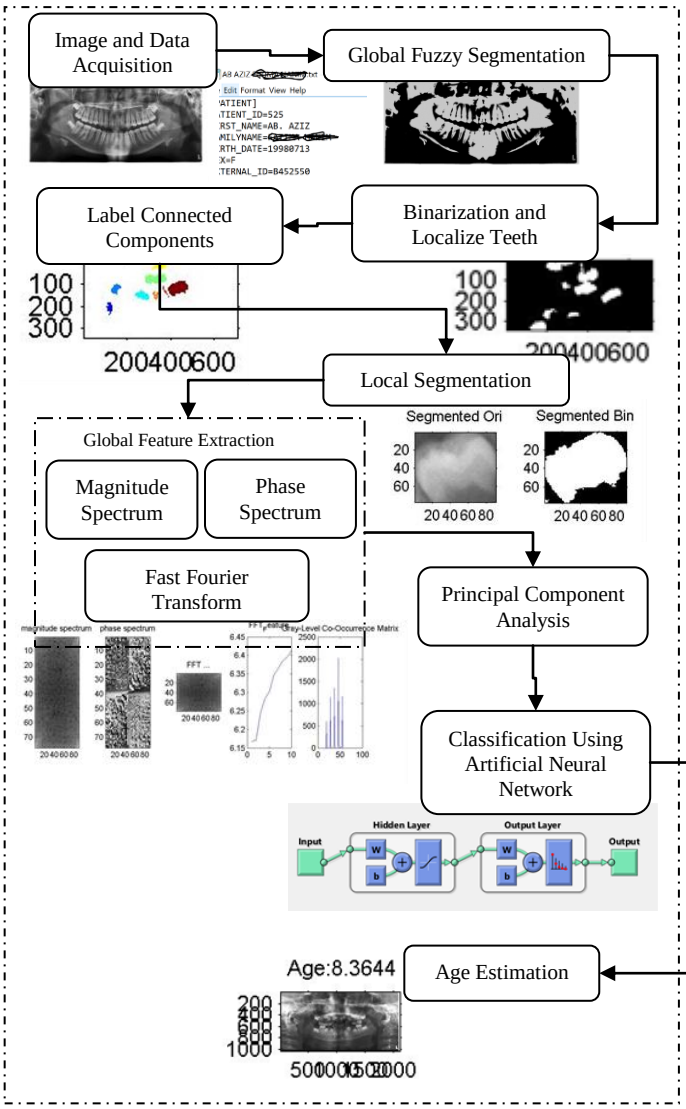

Fig. 1. Children Automatic Age Assessment Framework

As presented in Fig. 1. The steps of the age assessment technique have been defined and visualized. In the first step of the algorithm, the orthopantomography radiology images are captured and the patient information are recorded in a text file along with the X-ray images. This process have been done in a long process by medical experts in University Sains Islam Malaysia. This process have been accomplished in several steps and different experts monitored and evaluated the information to create a reliable and accurate dataset for further research studies. A text file including the patient information is available beside each high-resolution image in the dataset. The new developed dataset is called Malaysian Children Dental Development (MCDD) [10]. MCDD contains X-Ray images and the patient information of 456 people collected from Malaysian children aged 1 to 17 years old were collected from the collection stored at the department of the dentistry research at Universiti Sains Islam Malaysia. The information related to age and sex distribution of the collected dataset is shown in Table I. We categorized the dataset information based on the patient ages into four age categories as Class of Patient (CoP).

TABLE I: The Distribution of Data Population

Category	Age	Male	Female	All
CoP1	1-5	22	22	44
CoP2	6-10	107	150	257
CoP3	11-15	67	66	133
CoP4	> 16	11	11	22
	Total	207	249	456

Each image and the corresponding text file is stored with the name of the patient in the dataset. The text file includes the patiend name, ID, birthdate, sex, doctor name, pixel size of the image, image capturing date, and some other information. The image capturing date and the birthdate of the patient have been used in order to creat the geound truth information for the classification stage of the age assessment. After the data capturing stage, and analysing the captured information, the images needs to be analysed in order to achieve the final results. These process includes 1. global fuzzy segmentation, 2. binarization and localizing the teeth in the segmented image, 3. labeling the segmented image using connected component analysis, 4. local segmentation in order to extract the region of interest, 5. extracting the features, 6. creating the target information using the ground truth information which described earlier, 7. Feature selection using principal component analysis (PCA), 8. Create the Artificial Neural Network, and finally, 9. Estimate the age based on the classification result. We solve the segmentation problem using Fuzzy c-means (FCM) [11] which is a method that allows each data point to belong to multiple segments with varying degrees of membership. FCM is based on the minimization of the following objective function

$$I_m = \sum_{i=1}^{i=D}\sum_{j=1}^{j=N} \mu_{ij}^{m} \left\| x_i - c_j \right\|^2, \qquad (1)$$

where D is the number of data points, N is the number of clusters, m is fuzzy partition matrix exponent for controlling the degree of fuzzy overlap, with $m > 1$. Fuzzy overlap refers to how fuzzy the boundaries between clusters are, that is the number of data points that have significant membership in more than one cluster, x_i is the ith data point. c_j is the center of the jth cluster. μ_{ij} is the degree of membership of x_i in the jth cluster. For a given data point, x_i, the sum of the membership values for all clusters is one. FCM performs the following steps during clustering: 1. Randomly initialize the cluster membership values, μ_{ij}. 2. Calculate the cluster center:

$$c_j = \frac{\sum_{i=1}^{i=D} \mu_{ij}^m X_i}{\sum_{i=1}^{i=D} \mu_{ij}^m} \quad (2)$$

3. Update μ_{ij} according to the following:

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{k=N} \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|} \right)^{2/m-1}} \quad (3)$$

4. Calculate the objective function, J_m. 5. Repeat steps two–four until J_m improves by less than a specified minimum threshold or until after a specified maximum number of iterations.

After a global segmentation approach, the location of the interest which is the bottom right of the image is extracted. This process implemented based on finding the horizontal line which separates the upper and lower teeth and identifying a vertical line which identifies the left and right side of the mouth. In the next step, the image is binarized and connected component are labeled based on the following processes: firstly, scan all image pixels, assigning preliminary labels to nonzero pixels and recording label equivalences in a union-find table. Then resolve the equivalence classes using the union-find algorithm [12]. Finally, relabel the pixels based on the resolved equivalence classes.

In the next step, the features are extracted based on Fourier transform. The magnitude and phase spectrums are achieved based on shift zero-frequency component of the Fourier shift. Equation (4) defines the discrete Fourier transform Y of an m-by-n matrix X:

$$Y_{p+1,q+1} = \sum_{j=0}^{j=m-1} \sum_{k=0}^{k=n-1} \omega_m^{jp} \omega_n^{kq} X_{j+1,k+1} \quad (4)$$

where ω_m and ω_n are the complex roots of unity: $\omega_m = e^{-2\pi i/m}$, $\omega_n = e^{-2\pi i/n}$, i is the imaginary unit, p and j are indices that runs from 0 to m-1, and q and k are indices which run from 0 to n-1. In this case the spectrum is calculate based on Equation (5):

$$S = 100\left(Log\left(\|1 + Y_{p+1,q+1}\|\right)\right) \quad (5)$$

These features of the local segmented parts in different images have been used as the input feature of the training set in ANN. The target set for ANN is defined based on the given information for each patient in the supportive text file as mentioned earlier. The networks is trained and the classification result has been recorded as the result of the system. Table II presents the classification result of the automatic age assessment technique using fuzzy global segmentation technique. The result indicates that the automatic assessment can be achieved without human operation. This enables the experts to analyze the result information and collect meaningful information for their goal in dentistry, orthodontic and forensic.

TABLE II: THE AUTOMATIC AGE ASSESSMENT RESULT

Category	Age	Classification Rate (%)		
		Female	Male	All
CoP1	1-5	76.25	75.22	75.73
CoP2	6-10	78.48	77.32	77.90
CoP3	11-15	88.01	89.67	88.84
CoP4	> 16	87.35	85.74	86.54
	Total Average	82.52	81.98	82.25

Fig. 2 presents the gradient and validation values of the trained neural network for the input features extracted from different source images.

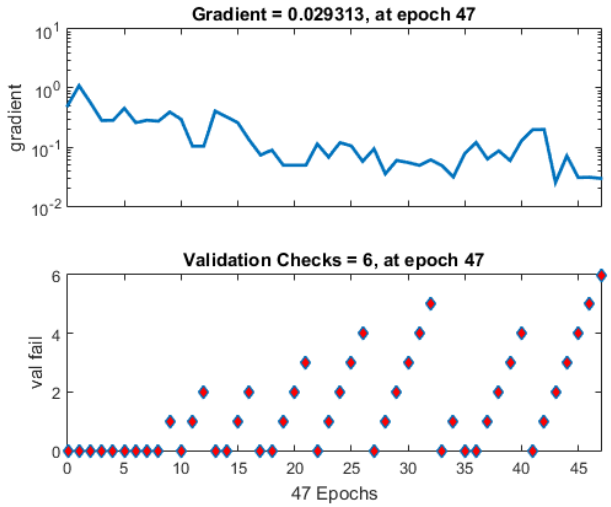

Fig. 2. Gradient and Validation values of the training process of neural networks.

III. CONCLUSION

Automatic age assessment is an important task in dentistry, orthodontic and forensic fields. We proposed a new framework of the age assessment based on fuzzy segmentation, phase and magnitude spectrums of the fuzzy shift for feature extraction. We trained artificial neural network based on the input features and target which achieved using patient information which collected during the data capturing process. The result of the classification for both male and female patient achieved promising result which indicate that the proposed technique can successfully automate this process without human operation. In the next step of our research, we are going to include more input data and features based on optimizing the feature vector to improve the classification rate. This will allow us to define more classes which lead us to achieve more precise age estimation result.

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