An Age Estimation Method to Panoramic Radiographs from Indonesian Individuals

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Abstrak

Fitur-fitur gigi dapat dipertimbangkan sebagai kandidat terbaik untuk pengidentifikasian PM. Jika data AM tidak tersedia, maka bantuan ahli forensik gigi diperlukan untuk membatasi ruang populasi data dan meningkatkan ruang pencarian data dengan pembuatan profil gigi pasca kematian atau postmortem dental profiling. Usia adalah salah satu faktor yang penting dalam membangun atau menentukan identitas seseorang. Inspeksi manual pada radiografi gigi memiliki dua kelemahan, yaitu intraobserver error dan interobserver error. Pada makalah ini diusulkan sebuah sistem semi-otomatis untuk estimasi usia. Terdapat dua fase dalam pengembangan sistem yang diusulkan, yaitu: fase pemodelan dan fase estimasi. Fase pemodelan adalah tahap untuk menurunkan rumus estimasi berdasarkan data yang sudah diketahui. Pada penelitian ini, digunakan data dari suku Jawa. Fase estimasi meliputi proses penentuan region of interest (ROI), penghitungan panjang gigi secara otomatis, dan estimasi usia berdasarkan rumus pemodelan yang telah dibentuk sebelumnya. Percobaan pada penelitian ini menunjukkan hasil yang menjanjikan, yaitu nilai rata-rata absolute error sebesar 5,2 tahun, jika dibandingkan dengan aplikasi metode Kvaal pada orang-orang Turki yang menghasilkan selisih lebih dari 12 tahun.

Kata kunci: *estimasi usia, radiografi panoramik, regresi, identifikasi manusia, pengolahan citra.*

Abstract

Dental features can be considered as the best candidate feature for post-mortem identification. If ante-mortem data is unavailable, then forensic experts are needed for reducing the search space by creating post-mortem dental profiling. Age is one of important factors in dental profiling. Manual inspection of dental radiographs suffers from two drawbaks, i.e., intraobserver error and interobserver error. This paper proposed a semi-automatic system for age estimation. There are two phases in developing the proposed system, i.e., the modeling phase and the estimation phase. The modeling phase is the stage for deriving an estimation formula based on known data. In this paper, we use data taken from Javanese people. The estimation phase include the process of defining a Region of Interest (ROI), automatic length computation, and age estimation based on the derived modeling formula. Our experiments showed a promising result, i.e., an average absolute error of 5.2 years, compared to application of the Kvaal method to panoramic radiographs from Turkish individuals that yields a difference of more than 12 years.

Keywords*: age estimation, panoramic radiographs, regression, human identification, image processing.*

1. Introduction

Forensic radiology is a part of forensic medicine that studies about human identification using postmortem radiographs of human body parts including skeleton, skull, and teeth. The identification is carried out by comparing postmortem data with antemortem data of a subject in order to find similar records. When the identification is performed two weeks after subject's death, a postmortem biometric identifier should be able to handle decay or severe body damage

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caused by fire or collision [1]. Dental features can be considered as the best candidate for postmortem identification. This is due to the strengthness and variation of dental features available.

In traditional methods, dental based identification depends on information such as missing teeth or teeth performance. With the enhancement of dental medicine studies and dental treatment methods by dentists, those traditional methods are unreliable now. Therefore, it is very important to develop new methods using dental features for identification [2], [3].

If antemortem data is not available, then an aid from dental forensic experts is required to reduce the data population space and increase the antemortem search space. This process is generally called as postmortem dental profiling. Information from this process can result in more focused antemortem data searching.

Age is one of many important factors used to develop or define an identity. An age estimation is a procedure commonly performed by anthropologists, archaeologists, and forensic experts. Dental radiographs are inspected and compared with radiograph images in order to produce scores that helps defining subject's age. The inspection process is performed manually.

There are two disadvantages of manual inspection, especially because the characteristics of dental radiograph images that have low contrast. Firstly, the manual inspection may produce an intra observer error, that is, a different inspection analysis result by an expert in two different observation times. Secondly, the manual inspection can result in an error inter observer, that is, a different inspection analysis result by two different experts.

In case of age estimation, some researchers have been using computer aided application for determining parts of dental radiographs (pulp, tooth boundary, root). Examples of the application are AutoCAD2000 [4], Adobe Photoshop [5], etc. However, those applications still need expert decisions such as how to determine pulp area or tooth boundary. Thus, they still suffer from intra observer and inter observer error.

This paper proposes an automatic approach to age estimation using panoramic radiographs. We firstly develop a model for estimation by analyzing dental features on Indonesian individuals. Secondly, using the model from the previous step, we analyze the performance of the model. Lastly, we develop an age estimation system that receives panoramic images and estimate the age of the subject requested.

2. Research Method

Panoramic radiographs used in this paper were obtained from 31 individuals by the same dentist. The population were from West Java, Indonesia, consisted of 30 women and only 1 man, with ages ranging from 50 to 73 years.

Initially, we developed a model for estimation by analyzing dental features. We measured the length of selected teeth then analyze the measurements using MS Excel 2007 software. We selected teeth from both sides of the jaw and only those teeth presented in [6] were selected.

Figure 1 shows the international dental numbering system which we used as our numbering system in this paper. There are 32 teeth in adult people, sixteen teeth on each jaw. There are two jaws, maxilla and mandible. Each jaw is divided into two groups, left and right. Thus, each group consists of eight teeth comprised of two bicuspid, one cuspid, two premolar teeth, and three molar teeth. In this research we only selected maxillary central and lateral incisors, maxillary second premolar, mandibular lateral incisor, mandibular canine, mandibular first premolar (see Figure 1).

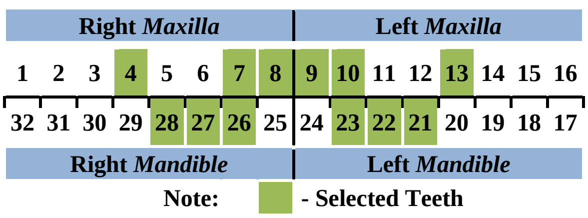


Figure 1. A system of dental numbering in adults

After measuring manually the lengths of selected teeth, we analyze the correlation value each tooth's length and the age. Next, we derived linear regression models using tooth lengths that were significantly correlated with age.

In addition, we developed an automatic system for computing tooth lengths. Given a digital panoramic radiograph, users can determine the top left and the right bottom boundary of a particular tooth. Next, the system will process this Region of Interest (RoI) into a binary image using our previous methods in [7]. Using the binary image, we can compute the tooth length using a vertical projection based method [8, 9]. Using the derived regression model, we estimate the age based on the tooth length. The design of our proposed age estimation system is as shown in Figure 2.

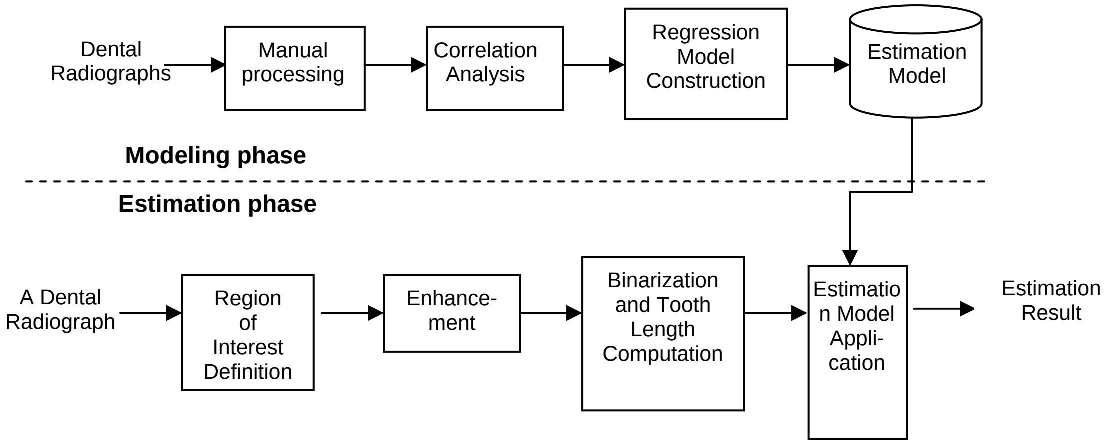


Figure 2. Design of the proposed age estimation system

3. Results and Analysis

The measurements from manual observations of selected tooth length are shown in Table 1. Some images does not contain some teeth, therefore we put NA (not available) and do not take into account those teeth in our next stages.

After we measured the selected tooth length, next we calculate the correlation value between the lengths of each numbered tooth with the chronological age provided in our dataset as in Equation (1).

$$Correlation(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}} \quad (1)$$

The correlation between selected tooth length and person's age is as shown in Table 2. We can see that the higher correlation score is achieved by canines in mandibular (left and right) followed by premolars also in mandibular (lower jaw).

Using the highest correlation value as in Table 2, we develop a regression model to estimate age based on mandibular canine (tooth number 27) lengths. The estimation formula derived was as in Equation (2).

$$age = 84.5426 - 0.0385\, x_1 \quad (2)$$

Next, we computed the estimation age using formula in Equation (2). Our results showed that the average absolute difference between the predicted and the chronological age was relatively small, i.e. 4.2 years.

Based on the derived estimation formula, we developed an automatic system able to estimate age based on a dental panoramic radiography. Firstly, the user provides top-left and bottom-right corners of a canine. Our system will automatically crop the panoramic radiographt into a region of interest (ROI) based on the corners provided. Next, the system enhances the ROI and transforms it into a binary one. After that, the tooth length can be computed based on it’s vertical integral projection. Finally, using a particular age estimation formula, a predicted age can be computed.

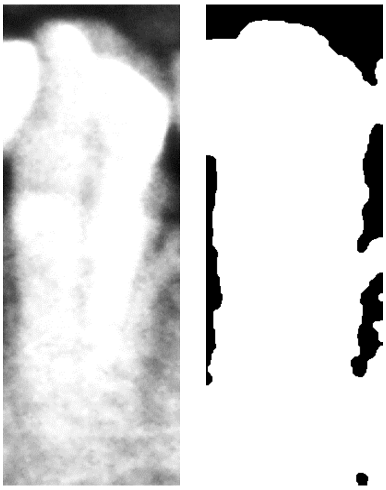
Table 1. Manual measurements

	Upper Jaw (Maxillary) - right to left						**Lower Jaw (Mandibular) - right to left**					
No	**Lateral and Central Incisors**				**Premolars**		**Lateral and Central Incisors**		**Canines**		**Premolars**	
	7	**8**	**9**	**10**	**4**	**13**	**26**	**23**	**27**	**22**	**28**	**21**
1	716	573	617	679	638	635	377	372	490	546	532	552
2	651	639	660	649	682	635	454	474	569	585	560	563
3	538	482	488	558	551	579	520	479	520	507	535	617
4	645	694	703	694	640	656	562	626	651	646	627	602
5	552	643	*NA*	606	508	591	477	449	593	560	*NA*	573
6	595	576	551	568	*NA*	*NA*	451	454	534	615	513	532
7	580	612	607	595	600	639	511	479	570	570	563	520
8	604	556	581	578	576	*NA*	426	416	496	516	521	516
9	*NA*	509	*NA*	*NA*	580	*NA*	437	413	541	518	550	547
10	664	676	683	*NA*	612	648	441	601	560	*NA*	646	604
11	595	617	620	612	639	587	508	519	648	632	574	532
12	599	662	613	580	568	609	520	514	602	618	523	580
13	554	559	547	*NA*	557	*NA*	403	434	509	524	537	518
14	559	656	644	565	571	*NA*	444	444	534	521	544	537
15	701	756	671	607	*NA*	677	530	496	642	673	587	564
16	646	481	529	604	684	662	491	460	600	602	499	587
17	*NA*	*NA*	*NA*	*NA*	*NA*	654	577	532	568	603	671	*NA*
18	643	684	710	666	*NA*	*NA*	487	498	679	647	*NA*	558
19	*NA*	*NA*	858	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	580	*NA*
20	693	782	744	630	582	692	594	588	762	705	645	*NA*
21	760	753	732	684	*NA*	*NA*	462	486	553	608	581	*NA*
22	649	643	643	654	649	592	625	552	643	629	667	643
23	624	606	685	624	660	613	612	571	630	655	590	599
24	573	*NA*	639	623	684	661	517	519	651	626	671	633
25	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	492	579	*NA*	611	*NA*	*NA*
26	*NA*	734	691	601	624	596	261	216	395	393	*NA*	*NA*
27	704	805	734	674	*NA*	681	507	469	561	530	*NA*	601
28	666	699	731	598	608	618	506	506	538	566	505	535
29	577	553	537	507	687	681	606	510	739	*NA*	701	664
30	626	623	611	580	*NA*	287	*NA*	527	675	675	622	*NA*
31	*NA*	593	588	*NA*	*NA*	*NA*	*NA*	631	569	588	*NA*	*NA*

Table 2. Correlation Analysis Results

Tooth number	Position	Tooth type	Number of individuals	Correlation value
27	Mandibular	Canine	29	-0.463376336
22	Mandibular	Canine	28	-0.266467997
28	Mandibular	Premolar	25	-0.193957433
21	Mandibular	Premolar	23	-0.191435637
26	Mandibular	Lateral incisor	28	-0.179354086
7	Maxillary	Lateral incisor	25	-0.29823082
23	Mandibular	Lateral incisor	30	0.12305
10	Maxillary	Lateral incisor	24	-0.026326473
8	Maxillary	Central incisor	27	-0.025632532
4	Maxillary	Premolar	21	-0.14246
9	Maxillary	Central incisor	27	-0.07274
13	Maxillary	Premolar	21	-0.01552

Figure 2. A dental panoramic radiograph



Left Right

Figure 3. Left: A sample region of interest (ROI). The user chose the top-left and right-bottom corners of a canine. Right: A binary version of an ROI.

As an illustration, Fig. 2 shows a sample radiography with a known chronological age = 66. Fig. 3 (left) shows a cropped ROI, which is a mandibular canine and it's binary version is as shown in Fig. 3 (right). The computed length was 516 pixels, resulting in an estimated age = 64.6936. Table 3 shows the results of our estimation system on our dataset. The average absolute error of our estimation system was 5.2 years.

4. Conclusion

The proposed system firstly asks users to select an ROI, i.e the top-left and bottom-right corners of a mandibular canine. Figure 4 and 5 show this process. This process still needs human interaction. Figure 6 shows the resulted ROI and the output of the system. Future works may develop a fully automated system that is able to define a particular tooth automatically.

This research uses a limited number and limited race of Indonesian individuals, i.e. Javanese people only. Therefore, in the future, the database should be added by more individuals from different races.

However, our experiments showed a promising estimation result, i.e. an average absolute error of 5.2 years, compared to application of the Kvaal method to panoramic radiographs from Turkish individuals that yields a difference of more that 12 years [6] .

Table 3. Estimation Results

No	Chronological Age (years)	Estimated Age (years)	Absolute Error (years)
1	66	65.0783	0.9217
2	61	63.3088	2.3088
3	67	63.6165	3.3835
4	60	59.7314	0.2686
5	60	59.6544	0.3456
6	61	63.078	2.078
7	60	62.3471	2.3471
8	68	65.0783	2.9217
9	61	66.5016	5.5016
10	73	64.1935	8.8065
11	57	60.3084	3.3084
12	61	61.1546	0.1546
13	63	64.5013	1.5013
14	70	63.3473	6.6527
15	54	62.1163	8.1163
16	58	63.4242	5.4242
17	71	62.3087	8.6913
18	58	60.7315	2.7315
19	52	60.4622	8.4622
20	56	64.5397	8.5397
21	57	64.3859	7.3859
22	73	63.2319	9.7681
23	65	62.3471	2.6529
24	62	69.4251	7.4251
25	50	65.1552	15.1552
26	71	65.1937	5.8063
27	54	63.6935	9.6935
28	57	61.1162	4.1162
29	71	62.4625	8.5375

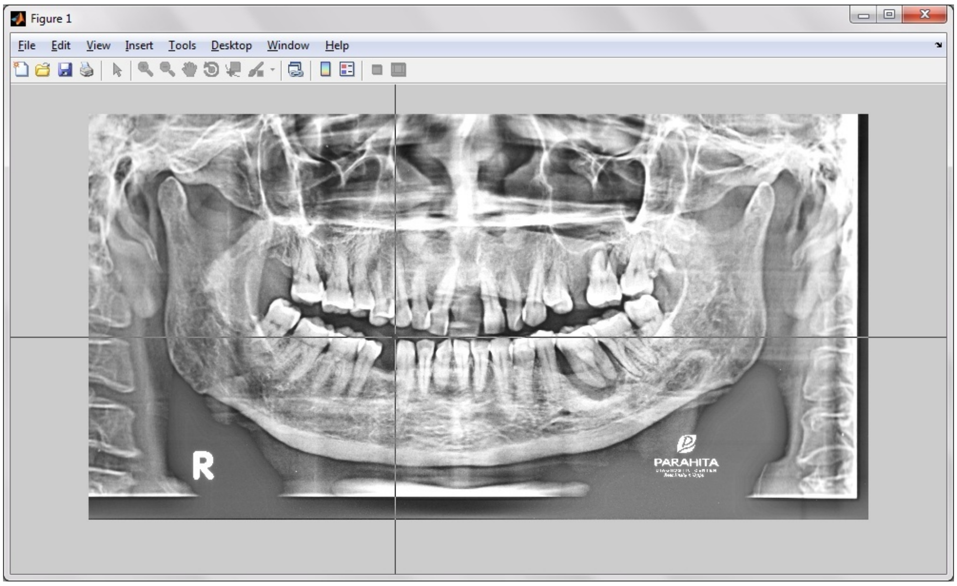


Figure 4. A process of defining the top-left corner of an ROI

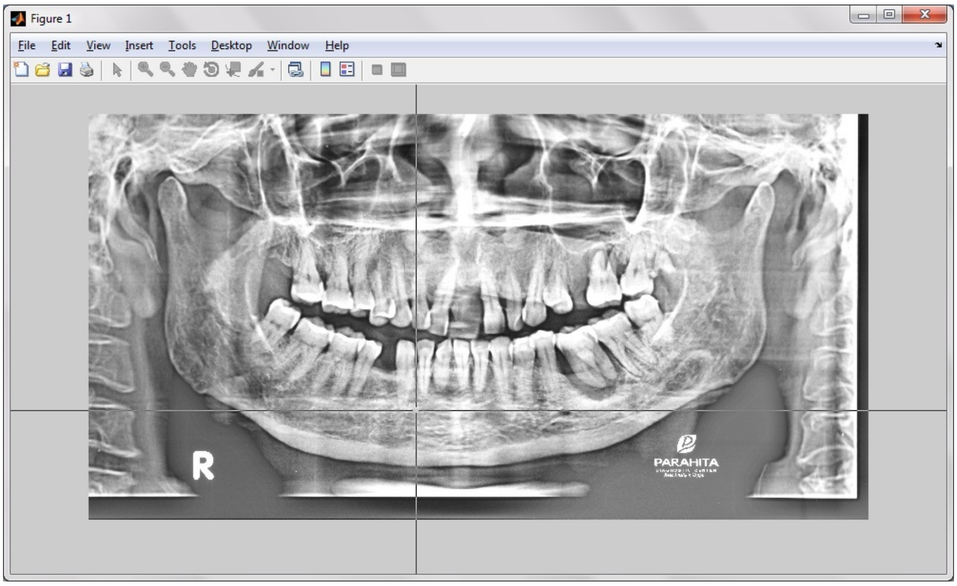


Figure 5. A process of defining the bottom-right corner of an ROI.

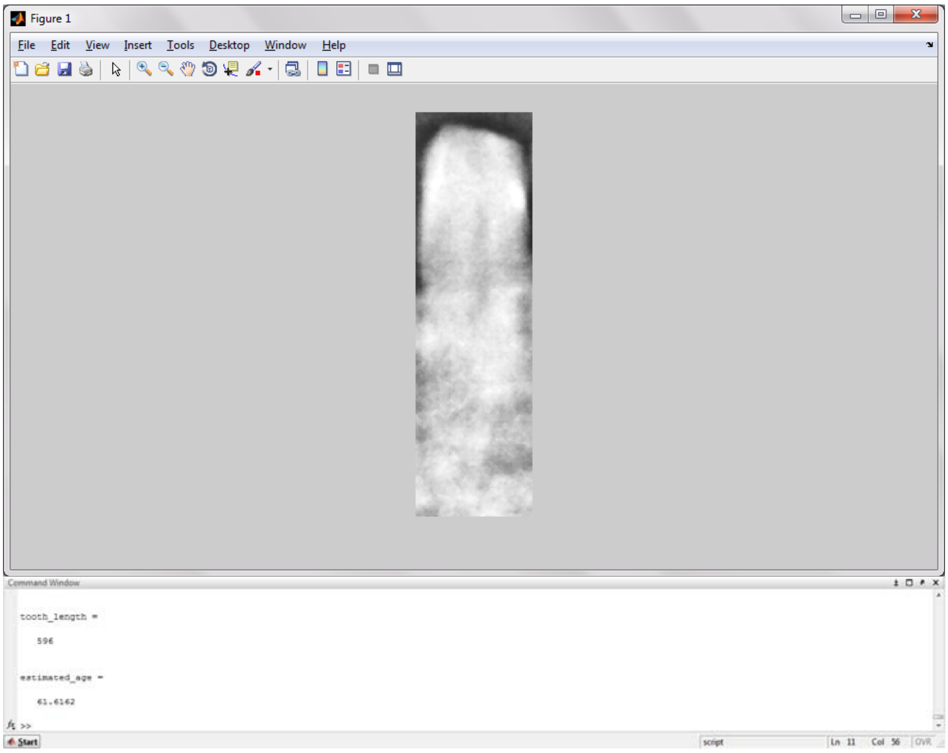


Figure 6. The output of the proposed system.

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