Forensic Identification System using Dental Panoramic Radiograph

Nabilah Ayu Permata
Department of Informatics and Computer Engineering
Politeknik Elektronika Negeri Surabaya, Indonesia
nabilahpermata@ce.student.pens.ac.id

Setiawardhana
Department of Informatics and Computer Engineering
Politeknik Elektronika Negeri Surabaya, Indonesia
setiawardhana@pens.ac.id

Riyanto Sigit
Department of Informatics and Computer Engineering
Politeknik Elektronika Negeri Surabaya, Indonesia
riyanto@pens.ac.id

***Abstract*—Forensic odontology is one method of determining the identity of the individuals who use it as a base dental identification. Teeth can provide information about the individual's identity because of its distinctive. Currently, the process of forensic identification through dental radiography is performed manually so it took a long time to match the teeth with human identity. Therefore, we need a system that can identify human identity quickly and accurately through dental radiography. In this experiment develop a system to identify human identity through dental radiography image quickly and accurately. The method of active shape model used for segmentation of mandibular teeth, this method can do shape search, to get the most appropriate shape. So that will get contours in accordance with the desired contour. This can help provide great results for the next stage. Then the extraction method used is Hu moment invariant, from this stage we will get 7 values that are free of rotation and scaling, so later if there is radiography that occurs the shift will still be detected. This experiment used 20 training data for segmentation, and 75 data dental radiograph images that has different shift for matching stage. The results of this research show success with an average of 82.67%. The proposed research method for this forensic identification system can be an appropriate system for the process of identifying a person based on dental radiography images.**

Keywords—Forensic Identification; Forensic Odontology; Active Shape Model; Human Identity

I. Introduction

Forensic identification is an attempt made with the purpose of assisting the investigator to determine the identity of an individual. The identification process in addition to being a basic right for disaster victims is also important for the identification of living individuals such as cases of identity fraud, marriage, athletes, child custody, immigration, or justice. Forensic odontology is one method of determining the identity of individuals who use teeth as the basis of identification. The superiority of this identification technique is not only due to its high accuracy that it almost matches the precision of the fingerprint technique, but due to the fact that the tooth is the most biological material resistant to environmental change and is protected. Teeth can also provide information about individual identity because of its distinctive features [2].

Identification of the death toll through the teeth has a high contribution in determining human identity. Dental identification procedures are positive method for identification. This procedure is a method that can be selected when the usual method of identification cannot be performed. Currently, the process of forensic identification via dental radiography is still manual so it takes a long time to match the teeth with human identity [2]. Therefore, it takes a system that can identify human identity quickly and accurately through dental radiography.

In this experiment will be developed a system to recognize human identity through dental radiography image. First, the dental radiograph image is used as system input, then preprocessing for image repair using median filtering and operator sobel. The next stage is segmentation to separate the image of the tooth by using the active shape model. Segmented tooth image will do feature extraction using Hu moment invariant method, then for matching human identity through dental radiography image using Euclidean distance method. It is hoped that the method proposed in this final project can provide accurate individual identification results and can assist investigators and forensic doctors in identifying individuals.

II. Metodology

This section represents the design of systems used for the system forensic identification using dental radiographic images. Processing in identifying human identity through teeth shape, described in the block diagram in Fig 1.

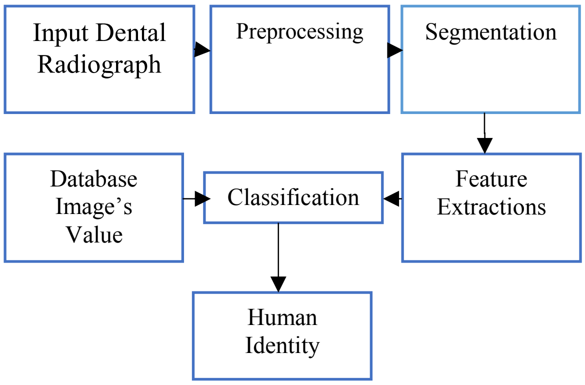


Fig. 1. Block Diagram of The Algorithm

This system will be done offline. In Fig 1. It is shown that the first stage performed is the dental radiograph image input, the radiographic image used in this final project is a panoramic image with extension .jpg. The second stage is to preprocessing the image to improve the image quality to be easily processed at a later stage, the preprocessing method used is the edge edge filtering. The third stage is segmentation, the method used is active shape model. The fourth stage is the feature extraction, to recognize the characteristics of a contour, the method used is moment invariant. The fifth stage is the matching of extracted input images with the extraction value of each person's radiographic image contained in the database using the Euclidean Distance method, so that the matching results obtained the identity of a person.

A. Input Dental Panoramic Radiograph

In this final project the radiographic image used as input is a panoramic image of the tooth with extension .jpg. The teeth used for this study were the mandibular teeth. Dental panoramic image data obtained from RSUD Dr. Soetomo Surabaya.

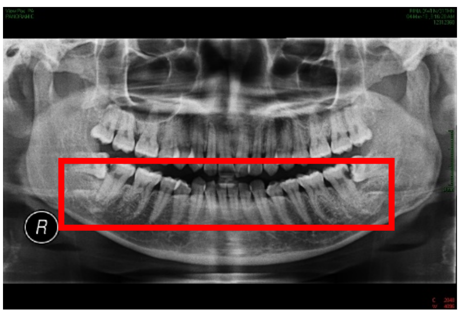


Fig. 2. Input Dental Panoramic Radiograph

B. Preprocessing

To improve the image quality of dental radiography to facilitate the next stage of processing it is necessary to do preprocessing. The method used for preprocessing is Sobel filtering for detecting edge teeth to facilitate the labeling stages of training sets using Sobel Edge Detector

C. Segmentation

After preprocessing, the next step is doing segmentation. This segmentation process is used to separate the tooth object that will be used for the identification process from the background. The method used is the method of Active Shape Model. The process in segmentation using Active Shape Model in Fig.3.

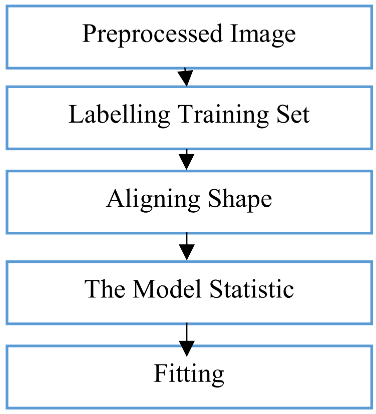


Fig. 3. Diagram Process of Active Shape Model

After preprocessing image, the next step is segmentation. The method used is active shape model. As Fig.3, There are 4 processes in segmentation using active shape model, that is first process is labeling training set. Labeling of training sets aims to provide user manual landmark point in the training data. The second process is the aligning shape, which aims to find convergent results from the point of a number of training data. The third process at this stage of segmentation is to obtain statistical value from PCA analysis which is used to reduce the value of aligning shape data to be easily computed at a later stage. The fourth process is fitting or image search that aims to find the shape of the tooth that matches the image input.

Labeling Training Set

The first stage of the labeling training set, conducted by the inner contours of each training of images described as a collection of n-pointed landmarks point manually marked by the user. In this study used 20 dental radiography data. Each dental radiography data is done 1 time training. Every 1 training data is 256 dots. Each contour can be described as a vector x ($x=[x_1,y_1,x_2,y_2,\ldots x_n,y_n]$) where ($x_i,y_i$) Is the position of the i-point landmark in the contour.

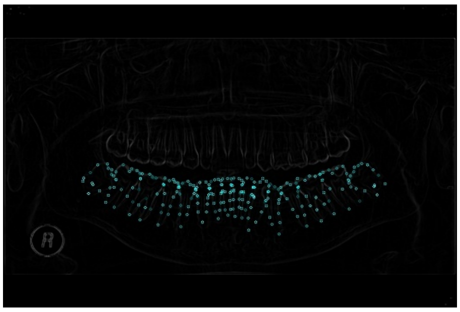


Fig. 4. Result of Labeling Proses

Fig. 4 and Fig.5 are the result of labeling training sets of dental radiograph images on the lower teeth (mandibular).

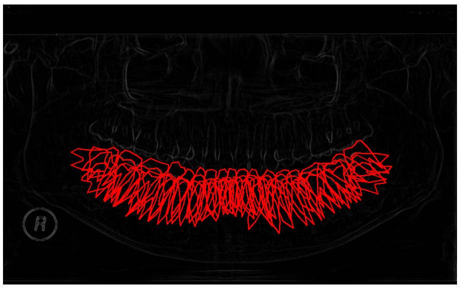


Fig. 5. Result of Labeling Training Set

Aligning Shape

The next stage after labeling the training set that is aligning shape, in the aligning shape stage is modeled by performing statistical tests on the point coordinates that have been labeled in the training set. To compare the equivalent points of different shapes, it must be adjusted with respect to the coordinate sources. Here we use an adjustment with scaling, rotation, and translation. So that the adjustment results obtained as quickly as possible and minimized the number of weights of distance between points equivalent in different forms.

Denoted a x_i which is a vector that describes the points of number n of the number -i form.

$$x_i = [x_{i0}, y_{i0}, x_{i1}, y_{i1}\ldots, x_{in-1}, y_{in-1}]^T, \text{ where } 1 \le i \le N \quad (1)$$

M[s,θ] [x] is the rotation θ and scale s. E.g. given 2 forms of the same object, x_i and x_j. Here we can use θ_j, and s_j and translation (t_{xj}, t_{yj}) that maps x_i to $M[s_j,\theta_j][x_j]$ to minimize the weights is:

$$M[s,\theta]\begin{bmatrix} x_{jk} \\ y_{jk} \end{bmatrix} = \begin{bmatrix} (s\cos\theta)x_{jk} - (s\sin\theta)y_{jk} \\ (s\sin\theta)x_{jk} + (s\cos\theta)y_{jk} \end{bmatrix} \quad (2)$$

The steps of aligning shape on a collection of shapes that amounted to N:

1. Rotate, scale, and translate each shape to align with the first shape in the set.
2. Repeat:
   a. Calculate the mean shape from the aligned shapes.
   b. Normalize the orientation, scale and origin of the current mean to suitable defaults.
   c. Realign every shape with the current mean.
3. Until the process converges.

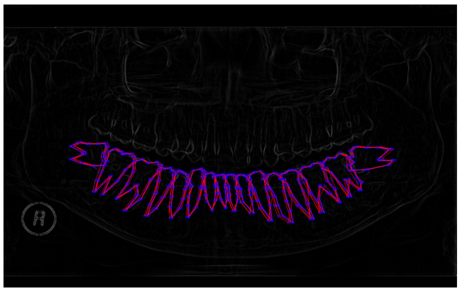


Fig. 6. Result of aligned shape

PCA (Principal Component Analysis)

Normalization of the mean to the scale and corresponding position in each iteration is to ensure that the algorithm is convergent. As a record of normalizing the mean of the form and then its adjustment for matching is not the same as normalization on each individual form. If each form is normalized on a scale by adjusting the distance between two points in a unit, the artificial correlation is forced into the set of shapes to change the model. However, if each form is adjusted or arranged with a mean, each form will have the same scale for the mean. In this case the position of the marker point will be chosen to be the most suitable means so as to produce a better model.

Denoted mean vector $\bar{x}$, and differential vector between vector xi and $\bar{x}$ as *d*xi, it can be written

$$dx_i = x_i - \bar{x} \quad (3)$$

and

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad (4)$$

The covariance matrix of the markers or landmarks of each form can be written with

$$S_x = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})(x_i - \bar{x})^T \quad (5)$$

After obtaining the covariance value of the matrix, then if the variation mode of the form points is expressed by $p_k(k=1\ldots 2n)$, then the characteristic vector units (eigenvectors) of S can be formulated as:

$$Sp_k = \lambda_k p_k,\ \lambda_k \geq \lambda_{k+1} \qquad (6)$$

By λ_k denotes value of eigenvalue number k from S, with $\lambda_k \geq \lambda_{k+1}$.

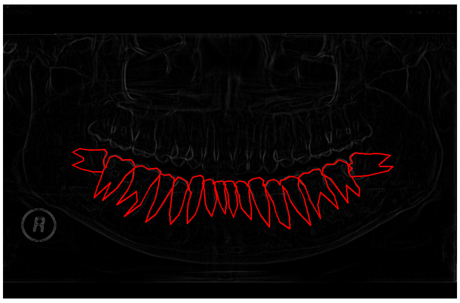


Fig. 7. Mean Shape

Fig 7. is mean shape that has got from the mean value of aligning shape.

Fitting Process

Stage after getting mean shape, eigenvector and a set of training data, then done fitting stage. Phase fittings are used so that the shapes constructed from the dot feature points can precisely represent the shape of the tooth present in the image being processed. This stage involves searching for the shape and pose parameters that because the exact model with the structure of the image. In the new image, the first form used is the mean shape.

The algorithm in the search shape and pose parameters as follows:

1. Initialize the shape parameters, **b (eigenvector)**, to zero (the mean shape).
2. Generate the model point positions using
$$\mathbf{x} = \bar{x} + \mathbf{Pb} \qquad (7)$$
3. Find the pose parameters (X_t, Y_t, s, θ) which best align the model points **x** to the current found points **Y** (See Appendix 6).
4. Project **Y** into the model co-ordinate frame by inverting the transformation T:
$$\mathbf{y} = T^{-1}_{Xt,Yt,s,\theta}(\mathbf{Y}) \qquad (8)$$
5. Project **y** into the tangent plane to $\bar{x}$ by scaling:
$$\mathbf{y}' = \mathbf{y}/(\mathbf{y}.\ \bar{x}) \qquad (9)$$
6. Update the model parameters to match to **y**
$$\mathbf{b} = \mathbf{P}^T(\mathbf{y}' - \bar{x}) \qquad (10)$$
7. If not converged, return to step 2.

The best shape results from the fitting process is as in Fig 8.

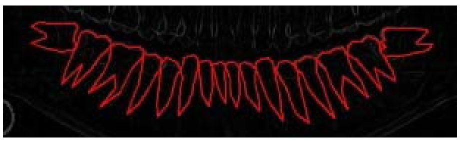


Fig. 8. Result of Fitting Process

D. Feature Extraction

The Feature Extraction process is performed after the dental radiograph has been segmented, this process aims to take a characteristic of the form that will get the value will be analyzed for the next process. Dental radiograph image of the tooth that has been segmented then detected canny to clarify the contours of teeth that have been segmented. After doing canny detection, the next stage is scanning white pixel to get the value of 4 quadrants of x maximal, x minimal, y maximal, y minimal which will be used to stage cropping the entire contour on the image. Fig 9. is the result from scanning white pixel of contour. Fig 10. is the result of crop selected contour.

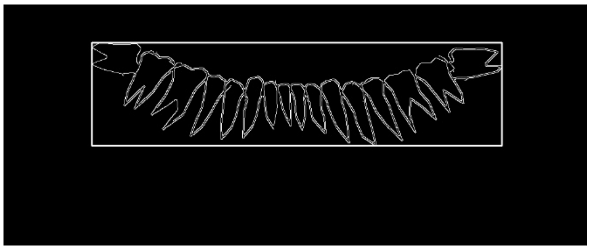


Fig. 9. Scanning White Pixel of Contour Teeth

Fig. 10. Cropping Selected Contour

The contours on the cropped image will be searched for value using 7 hu moment invariant which will be used for each radiographic image of each person. To get a value of 7 hu moment invariant, the first calculation of the calculated Moment invariant calculated discretely. Given a function $f(x, y)$, the moment is defined by:

$$M_{pq} = \iint x^p y^q f(x,y)dxdy \qquad (11)$$

Mpq is a two-dimensional moment of the function $f(x, y)$. The order moment is (p + q) where p and q are the real numbers. For implementation in digital form, this equation becomes:

$$M_{pq} = \sum_x \sum_y x^p y^q f(x,y) \qquad (12)$$

To normalize the translation invariant in the image field, the image centroid is used to determine the center moment. The gravity center coordinates of the image are calculated using the equations below and given by:

$$\overline{X} = \frac{M_{10}}{M_{00}} \quad \overline{Y} = \frac{M_{01}}{M_{00}} \tag{13}$$

Furthermore, the central moment can be determined discretely as follows:

$$\mu_{pq} = \sum_x \sum_y (x - \overline{x})^p (y - \overline{y})^q \tag{14}$$

The momentum is then normalized for the effects of scale change using the following formula:

$$\eta_{pq} = \frac{\mu_{pq}}{\mu_{00}^{\gamma}} \tag{15}$$

Where is the normalization factor :

$$\gamma = \left(\frac{p+q}{2}\right) + 1 \tag{16}$$

From the moment of normalization center, 7 values can be calculated and determined by:

$$\begin{aligned}
\phi_1 &= \eta_{20} + \eta_{02} \\
\phi_2 &= (\eta_{20} - \eta_{02})^2 + 4\eta_{11}^2 \\
\phi_3 &= (\eta_{30} - \eta_{12})^2 + (\eta_{03} - 3\eta_{21})^2 \\
\phi_4 &= (\eta_{30} + \eta_{12})^2 - (\eta_{03} + 3\eta_{21})^2 \\
\phi_5 &= (3\eta_{30} - 3\eta_{12})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\
&+ (\eta_{21} - \eta_{03})(\eta_{21} - \eta_{03}) x [3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \\
\phi_6 &= (\eta_{20} - \eta_{02})[(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{03})^2] \\
&+ 4\eta_{11}(\eta_{30} - \eta_{12})(\eta_{21} + \eta_{03}) \\
\phi_7 &= (3\eta_{21} - 3\eta_{03})(\eta_{30} + \eta_{12})[(\eta_{30} + \eta_{12})^2 - 3(\eta_{21} + \eta_{03})^2] \\
&+ (3\eta_{21} - \eta_{03})(\eta_{21} - \eta_{03}) x [3(\eta_{30} + \eta_{12})^2 - (\eta_{21} + \eta_{30})^2]
\end{aligned} \tag{17}$$

Fig.11 is 7 values from the result of feature extraction using Hu Moment Invariant method

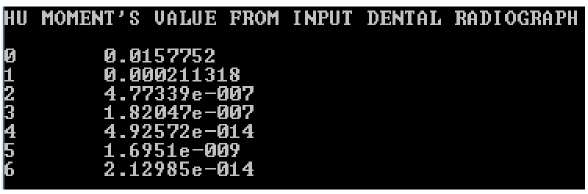


Fig. 11. Result of 7 Hu Moment Invariant

E. Matching

The process of matching the teeth in this final project is aimed to match the input teeth with the query teeth. The method for matching is using the Euclidean Distance method. The Euclidean distance matching method is chosen because this method is accurate to find the difference between the distance of the value of the feature extraction and the value located in the database. Using Euclidean distance, the value closest to one of the databases can be easily selected. This matching is based on the difference between the input teeth image (*p*) and each of the characteristic query extraction images (*q*). The formula for matching gear with the Euclidean Distance method is (18):

$$\text{Euc} = \sqrt{(p1 - q1)^2 + (p2 - q2)^2 + \ldots + (p7 - q7)^2} \tag{18}$$

TABLE I. RESULT EUCLIDEAN DISTANCE FOR 1 DATUM

7 Extraction value result of Gigi2.jpg (2th data)	*7 Database value of Gigi2.jpg*	*Euclidean Distance Value*
0.014789	0.014771	$1.80508e^{-005}$
0.00018474	0.00018411	
$3.55989e^{-007}$	$3.60735e^{-007}$	
$1.19648e^{-007}$	$1.21901e^{-007}$	
$2.15879e^{-014}$	$2.2399e^{-014}$	
$8.94237e^{-010}$	$9.1957e^{-010}$	
$1.19882e^{-014}$	$1.23179e^{-014}$	

The table I is one example of Euclidean distance results for 1 datum obtained. Where 7 values of feature extraction results are reduced by 7 values that are located database. Any reduction in the value of input characteristic of the input image with each value in the database is done squaring. After that is done summation, then all the sum of each deducted results that have been squared, the whole is raised. Then from 7 value of characteristic extraction result and 7 value of each image database will get 1 value. While Fig. 12 is the result of Euclidean distance for all database values used

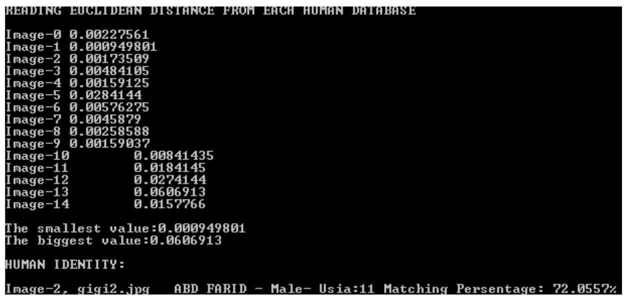
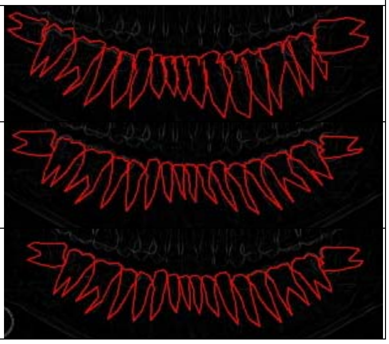


Fig. 12. Result of Identification Human Identity

III. EXPERIMENTAL RESULT

Before performing the final stage of the segmentation that is fitting process, first declare the number of iterations for the movement toward the best shape of the image. Table II. shows the effect of initializing iterations for movement to the best shape.

TABLE II. ITERATIONS FOR SEARCHING THE BEST SHAPE

Number of Iterations	**Fitted Images**
1	
2	
4	

From Table II, it can be seen that we can get the best pose or the best shape on the fourth iteration. In the fourth iteration the shape fitting closes to the desired shape, and even the shape of the fitting is almost the same as the desired shape. The desired shape or teeth is mandibular teeth that has 16 complete teeth.

After doing segmentation images, then do extraction features to take the value for database matching. The database obtained from the extraction of features that is as in the Table III.

TABLE III. RESULT OF FEATURES EXTRACTION FOR DATABASE MATCHING

7 Moment Invariant	**File Name**	
	Gigi2.jpg	***Gigi3.jpg***
ϕ_1	0.0167246	0.0175097
ϕ_2	0.000237616	0.000255127
ϕ_3	0.000000569285	0.000000444923
ϕ_4	0.000000234233	0.0000000532697
ϕ_5	0.000000000000080264	-0.00000000000000761694
ϕ_6	0.00000000246032	-0.000000000812529
ϕ_7	0.000000000000029558 4	-0.00000000000000303933

From Table III. shows that the results of some of the extraction feature data yield 7 different values that distinguish between dental radiograph images of one another. So that 7 values of each radiographic image, can be used as a database of matching stage values to recognize human identity.

TABLE IV. MATCHING PROCESS WITH DATABASE

7 Extraction value result of Gigi2.jpg (2th data)	***Database Value***	***Euclidean Distance***	***Minimum Value***	***Matching With***
•0.014789 •0.00018474 •3.55989e^{-007} •1.19648e^{-007} •2.15879e^{-014} •8.94237e^{-010} •1.19882e^{-014}	Gigi1	0.00033705 7	1.80508e-005	B-gigi2
	Gigi2	1.80508e-005		
	Gigi3	0.00219602		
	Gigi4	0.0051845		
	Gigi5	0.00258487		
	Gigi6	0.00227503		
	Gigi7	0.00486923		
	Gigi8	0.0102761		
	Gigi9	0.00245639		
	Gigi10	0.0018162		
	Gigi11	0.00095660 5		
	Gigi12	0.0078174		
	Gigi13	0.00425774		
	Gigi14	0.0053861		
	Gigi15	0.00278361		

From Table IV, we can see the result of matching process using Euclidean Distance, where 7 results of reduced feature extraction value and represented by 7 database values per image, have obtained Euclidean distance value for each image. From the results obtained Euclidean, then selected the most minimal results, the most minimal results that are selected because the value is closest to the value of a person's image database.

TABLE V. RESULT MATCHING

Image (.jpg)	**Matching with Database**		
	Human Identity	***Data Testing***	***Success (%)***
Gigi1	A-gigi1	5 data, 3 success	60
Gigi2	B-gigi2	5 data, 4 success	80
Gigi3	C-gigi3	5 data, 5 success	100
Gigi4	D-gigi4	5 data, 3 success	60
Gigi5	E-gigi5	5 data, 4 success	80
Gigi6	F-gigi6	5 data, 5 success	100
Gigi7	G-gigi7	5 data, 4 success	80
Gigi8	H-gigi8	5 data, 5 success	100
Gigi9	I-gigi9	5 data, 4 success	80
Gigi10	J-gigi10	5 data, 4 success	80
Gigi11	K-gigi11	5 data, 5 success	100
Gigi12	L-gigi12	5 data, 4 success	80
Gigi13	M-gigi13	5 data, 4 success	80
Gigi14	N-gigi14	5 data, 3 success	60
Gigi15	O-gigi15	5 data, 5 success	100
Success Average		75 data, 62 success	82.67%

Table V. shows the results of the identification process using the system created. As many as 15 person identities are used for the matching stage, for the data used are as many as 5 data that has a different shift for each person. System experiments using different shifts are used to find out how far the results of the feature extraction method and the Euclidean distance method work. The average of matching success using the proposed method is 82.67% of the 75 data used.

IV. CONCLUTIONS

The proposed method of identifying human identity through dental panoramic radiographic images. Segmentation on dental radiograph image is done by using Active Shape Model method can already fit to contour automatically, but the shape input must be defined. Feature extraction has been completed 100% well. The stage of identity matching is done on the identity of 15 person with each of 5 data that has a different shift. Of the 75 data conducted research, get an average success of 82.67%.

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