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Face Component Extraction Using Segmentation Method on Face Recognition System

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ABSTRACT

Biometric technology has been frequently utilized in identifying and recognizing human components. This technology identifies human's unique and static body parts, such fingerprints, eyes, and face. One of the most biometric technologies which are widely used is facial recognition. The identification and recognition of a human face utilize the face components' processing and analysis. This technique consists of determining face components' region and their characteristics, which establishes the role of individual component in face recognition.

This research develops a system that defines face components by determining the distance of face components (i.e.: the eyes, nose, mouth) and other facial components. This process conducted on a frontal single still image to acquire the components. Distances between components are determined by detecting the based skin color, cropping to normalize face region, and extracting eyes, nose, and mouth components. This research utilizes 150 Indonesian face samples and has successfully determined the face components'. From the experiment we conclude that the determination of face components and face components' distances can be used to identify a face as a subsystem of a face recognition system. Test of uniqueness to 150 samples has succeeded. The result indicated that eight face component distances give better result than the previous one, which only applied three components distance. The test of uniqueness with eigenspace showed the existence of different characteristic for every face image.

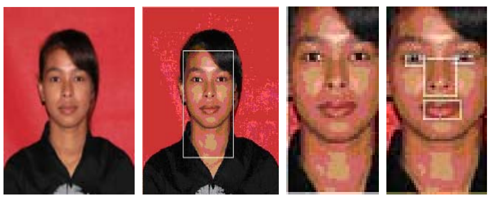
Keywords: *distance, extraction, face component, face recognition, segmentation*

1. INTRODUCTION

Biometric technology is an automated method to identify human based on biological and behavioral characteristics. Face recognition system is one kind of systems in biometric technology [1]. It realizes configuration capture in establishing face components' differences to determine face component's local weight and separate internal and external components of a face. One of the researchers in face recognition system is face image detection from a single still image where the face image part is detected by skin color model analysis [2] [3]. The determination of face region in that research was not complete, because some parts of the face were not included in the extraction process. Hsu's research [4] [5], extracted face component frontally to get the eyes and the mouth parts, and the triangle between them. Zl´avik [6] realized that eyes have proportional distances from other face components. If one component is detected, the position of other components would be obtained and the component could be extracted. Based on those researches, the author develops a system that separates a face image into face components, and then extracts components in the regions of eyes, nose, mouth, and face boundary from a frontal single still image. Distances between components are measured and combined with other components.

2. FACE COMPONENTS EXTRACTION PROCESS

Principally, the research is conducted in automated steps illustrated in Figure 1. The first step is face detection based on skin color model. The result is then cropped to normalize the face region. Next, extraction of eyes, nose, and mouth components is conducted, and distances between them measured.



(a) (b) (c) (d)

Figure 1. Processing steps: (a) Input Image, (b) Detection, (c) Cropping, (d) Extraction

2.1 Face Skin Model Detection

Ninety skin samples of Indonesian faces are used. The extraction step is conducted by decreasing the luminance level to reduce lighting effects, such that the original image is obtained. Decreasing the luminance level is conducted by image conversion from RGB to YCbCr or chromatic color. After the Cb and Cr values are obtained

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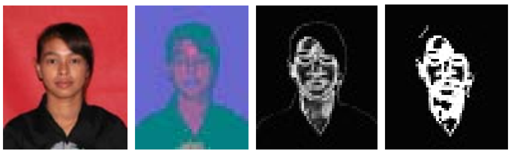
then the low pass filter is conducted to the image in order to reduce noise. The reshape function is next applied to Cb and Cr values which turn them into row vectors. Ninety row vectors are formed from each Cb and Cr values. All components of Cb become Cb vector elements, and all Cr components become Cr vector elements. The vector results of Cb and Cr are used to find Cb average value, Cr average value, and covariance of Cb and Cr. The average values of the samples are Cb = 102.6665, Cr = 147.3592 and Covariance (Cb, Cr) = {(231.443, 310.2558), (310.2558, 481.8651)}.

2.2 Face Detection Process on Normal Still Image

The size of the face image used for this research object is 300 X 300 pixels in JPG format. Face detection process begins with skin model detection process by applying the threshold value to get the binary image (as shown in Figure 2).



(a) (b) (c) (d)

Figure 2. (a) Single still image, (b) Image converted to YCbCr format, (c) The result of Gaussian distribution, (d) Threshold process results in binary image.

2.3 Face Cropping Process on Normal Static Image

The binary image obtained from threshold process is further processed to take and crop the face part of the image. The face image is the part in white color (pixel value = 1). These processes are as the following steps [2]:

1. Separating the skin part of the face from those of non face part, such as arms, hands, shoulders.
2. Determining the hole area of the picture which indicates the face region. We use the following equation to indicates the hole are as the face region:

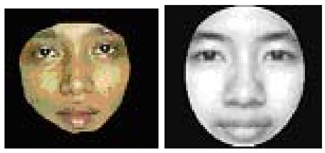
   $$E = C - H \qquad (1)$$

   Where E is Euler number, C is related component number and H is hole number in the region.
   By using this equation, the value of H can be found by calculating H = 1 – E, to obtain the skin region of the face.
3. Finding the statistic of color value between the hole area of the picture (which indicates the face area) and the face template picture after the hole that represents the face region has been determined. The following equations are used to find the center of mass in determining the face part position of the picture:

$$\bar{x} = \frac{1}{pic\_area} * \sum (row\_el * pic\_el) \qquad (2)$$

$$\bar{y} = \frac{1}{pic\_area} * \sum (col\_el * pic\_el) \qquad (3)$$

This process uses a different face template from the Rademacher's research used. Rademacher's research used the Figure 3a, while we used the improved template as in Figure 3b. The fundamental differences between these two templates are the face position in the whole template and the size of black region around the image. The difference in face skin color in the template has no significant effect to the face result obtained.
Moreover, the face position in Rademacher's template was not symmetric, which affected the final result.



(a) (b)

Figure 3. (a) Face template in Rademacher's (b) Face improved template.

4. The previous process shows that after the analysis a picture that contains a human face has at least one hole or has the height width ratio of approximately 1. The angle of centre of mass that contains the face is determined by using the centre of mass of the face object position. The following equation is used to find such angle:

   $$\theta = 0.5 \tan\left(\frac{b}{a-c}\right) \qquad (4)$$

   Where

   a = ΣΣ (x') * 2 * pic_el
   b = 2 ΣΣ (x') * ΣΣ(y') * pic_el
   c = ΣΣ (y') * 2 * pic_el
   $x' = x - \bar{x}$
   $y' = y - \bar{y}$

5. Every step is conducted on all regions with color value of 1 in the binary image. If the ratio of height and width is between 0.6 and 1.2 then the segmented area is assumed to be a face, and its coordinate is saved in a row vector.
6. The coordinate values are used to form a rectangle surrounding the face (bounding box) in the image.
7. The bounding box in the original image is used as a boundary for the cropping process. The result is shown in Figure 1c.

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2.4 Extraction Process and Measurement of Distances between Face Components

The face region image as a result of face detection process is further processed to obtain the face components and the distances between them. This is conducted by extracting the eyes, nose, and mouth components. The extraction determines the components' locations, and is done on YCbCr color space to separate the luminance and chrominance components in order to reduce the lighting effect. Distances measured are between:

1. Left eye – right eye
2. Right eye – mouth
3. Left eye – mouth
4. Right eye – nose
5. Left eye – nose
6. Nose – mouth
7. Nose height
8. Nose width

The face extraction process in this research is conducted in three stages:

1. Face division.
2. Face components detection and extraction.
3. Measurement/calculation of distances between face components.

The face image from which the components will be extracted is first processed by dividing it into regions, in order to narrow down the area for detection. The extraction result can then be expected to be more accurate. The division also minimizes the probability of other components be detected [7]. Detection is conducted by computing the components of color space in regions assumed to be the locations of face components. These are extracted to determine the location of the components. The process of face components extraction is conducted next.

Face Division: The face is divided into three parts: face, eyes, and mouth regions. The face image to be divided must have forehead and chin regions minimum, and neck region maximum. Some improvements are done on the mouth region to get better result from the previous research [7]. The former research divided the mouth region as illustrated in Figure 4(a). An approximate position of the mouth is determined as the center of the region, vertically and horizontally. There exists a neck part that affects the mouth component position in the mouth region as the mouth component in this research is not always located vertically at the center of the region as is illustrated in Figure 4(b). The divisions of face image consider the image size and use the criteria of division that explained previously.

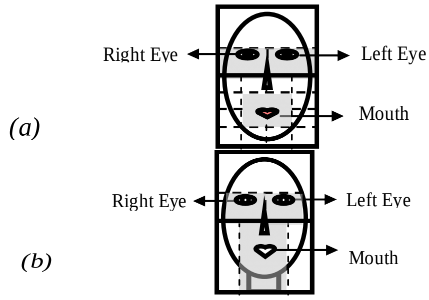

Figure 4. (a) Previous mouth region division [7]. (b) Improvement in mouth region division.

Face Component Detection and Extraction:

After the cropping process, component extraction is conducted as follows [7], [8]:

1. Eyes extraction is done by forming an eye map as shown in Figure 5.

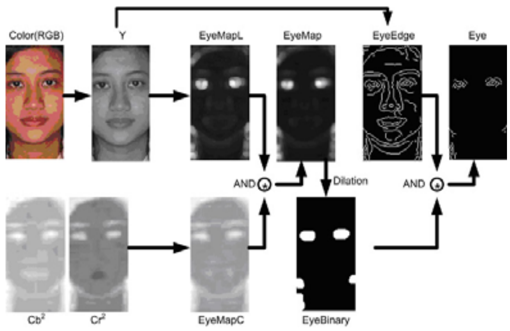

Figure 5. Eye map formation [4].

2. Mouth extraction is done by forming a mouth map, as pictured in Figure 6.

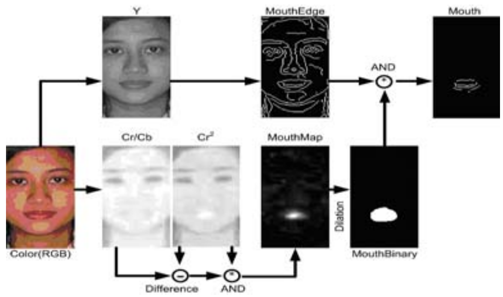

Figure 6. Mouth map formation [4].

3. Based on former researches [6], [8], nose extraction is conducted after the distance between left and right eyes' midpoints is determined. Nose height and width is determined as shown in Figure 7(a). The following equations compute the nose's size [8]:

$$Nose\_height = 0.75 * v \quad (5)$$
$$Nose\_width = 0.65 * l \quad (6)$$

Where
v : vertical distance between two eyes and nostril
l : vertical distance between two eyes.

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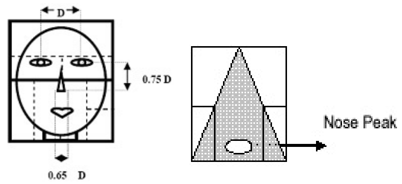
4. Nostril extraction is done after the nose can be extracted and the nose region is further divided into parts to obtain the nostril specific area. The division results in [7], [8] are Nose upper part and nose lower part, which consists of: lower right part, lower middle part, lower left part as illustrated in figure 7(b).



(a) (b)

Figure 7. Nose component geometry

Nose lower middle part is the nostril specific area. By mapping this area, the nostril is obtained. This nostril will act as a reference for measurement to and from the nose.

After the whole extraction process is completed then each face component is surrounded by a bounding box, except for the nostril which is marked by a dot. The result is shown in Figure 1(d).

Measurement of Distances between Face Components: The distances between face components are distances from certain points in every bounding box of face component that are:

1. The center point of right eye box.
2. The center point of left eye box.
3. The center point of mouth box.
4. Nose peak.
5. End points of nose width.

All distances between face components mentioned earlier are obtained from these five points. The face distances are obtained by calculating the difference between every point's coordinates if there exists a perfect vertical=horizontal lines connecting those points. Otherwise, the Pythagoras theorem is used, since additional lines can be drawn from the coordinates to form a right triangle. Face component distance is the diagonal side of the triangle. The value is rounded to the nearest integer.

Distances between face components used in this research are the ones between left - right eye, right eye - mouth, left eye - mouth, right eye - nose peak, left eye - nose peak, mouth - nose peak, nose height, nose width (as shown in Figure 8).

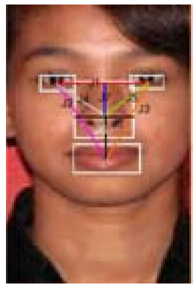


Figure 8: Determination of distances between face components.

The distances' combination forms the semantic that represent the uniqueness of face components:

J1 = right eye - left eye distance
J2 = right eye - mouth distance
J3 = left eye - mouth distance
J4 = right eye - nose peak distance
J5 = left eye - nose peak distance
J6 = nose peak - mouth distance
J7 = nose height
J8 = nose width

3. EXPERIMENTAL RESEARCH

This research uses 150 test images of frontal single human face with relatively different lighting condition. Test images are taken with digital cameras. The format is JPEG with 300 X 300 pixels resolution of RGB colors. Of the 150 sample images used, the combinations of those 8 distances (J1-J8) that give uniqueness to every face component are presented in Table 1.

This proves that from the perspective of face components as a whole, the eight distances shows that no face component is the same. J1-J3 shows that 140 data are unique in eyes and mouth triangle component. Component distance J4-J6 also shows that there exist 126 unique face images. The combination of J7 and J8 is for nose component. There is an only 42 unique face images, it means a number of 108 face images having the same measure. If the combination of eye - mouth, combination of nose and combination of nose component measure is merged, it gives a better result.

Table 1 Face uniqueness level

No	Component Distance Combination	Unique Number	Unique %
1	J1-J2-J3-J4-J5-J6-J7-J8	150	100
2	J1-J2-J3-J4-J5-J6-J7	150	100
3	J1-J2-J3-J4-J5-J6	150	100
4	J1-J2-J3-J4-J5	148	98.67
5	J1-J2-J3-J4	148	98.67
6	J1-J2-J3-J5	140	93.33
7	J1-J2-J3-J6	150	100
8	J4-J5-J6	126	84
9	J1-J2-J3	140	93.33
10	J7-J8	42	28

It showed with 150 face image data gives its uniqueness. The distance of right eye component - mouth (J2) with left eye component - mouth (J3) inconvertible, in meaning of J2 cannot represent J3, and vice versa. Right eye component distance – nose peak (J4) with left eye component distance - nose peak (J5) nor compatible. It shows that every face component or face form is not always symmetrically. Therefore if we want to know face uniqueness, these eight component distances need to be considered.

4. TEST OF FACE COMPONENT UNIQUENESS

Test of face component uniqueness used eigenspace method [9]. The test was conducted to the first 8 face images. Eigen value and Eigen vector were investigated to get the characteristic of face (see table 2 and table 3 at the end of this article).

The big eigen value shows dominant existence of face component characteristic. The biggest value 317.99 indicates that J1 is the most important component in finding other face component. The same Eigen value shows dependence each other from face component. From table 2 we can see second and third vector as well as eight and seventh vector have the same values. This indicates that component distance J2 and J3, also component distance J7 and J8 has the same proportion, nor for all face image. Every single Eigen value has vector showing face component characteristic.

5. CONCLUSION

This research shows that at least five face component distances are needed to obtain the uniqueness of face component distances. Validity of the uniqueness of face component distances cannot be maintained if only four or less face components are used. The minimum of face components used must be directly proportional to the number of data tested in order to get unique distances, as the uniqueness is significantly affected by the combination probability of all face component values. These component distances can further be used as a component in a face recognition system. Level of accuracy reached higher by using eight face component distances compared to three face component distances. Based on result of experiment on 150 face images, the percentage of three face component distances reached 93.33% unique, while for eight faces component distances increased to 100% unique. These eight face component distances forms face characteristic model through Eigen value and Eigen vector from eight distances matrix. Big Eigen value shows existence of the right eye - left eye distance, the most important component while same Eigen value shows each other dependence from face component. The determination of face components along with their distances has not guaranteed yet to recognize a face image because of equipment boundary, measurement, object captured and/ or abnormal face condition.

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Table 2. Eigen value (1.0e+002 *)

3.1799	0	0	0	0	0	0	0
0	-0.0505 + 0.0185i	0	0	0	0	0	0
0	0	-0.0505 - 0.0185i	0	0	0	0	0
0	0	0	0.0557	0	0	0	0
0	0	0	0	1.383824	0	0	0
0	0	0	0	0	-0.0046	0	0
0	0	0	0	0	0	0.0031 + 0.0027i	0
0	0	0	0	0	0	0	0.0031 - 0.0027i

Table 3. Eigen vector (1.0e+002 *)

-0.3282	0.3949 - 0.0925i	0.3949 + 0.0925i	0.0563	0.4068	0.0899	-0.1529 + 0.0871i	-0.1529 - 0.0871i
-0.3747	0.1691 + 0.3316i	0.1691 - 0.3316i	-0.5498	0.3181	-0.3651	-0.3790 - 0.0259i	-0.3790 + 0.0259i
-0.3592	-0.2233 - 0.2871i	-0.2233 + 0.2871i	-0.1068	0.0476	-0.3057	-0.2155 + 0.0415i	-0.2155 - 0.0415i
-0.3490	-0.2706 + 0.1837i	-0.2706 - 0.1837i	0.7861	-0.5965	-0.0180	0.4929 - 0.0602i	0.4929 + 0.0602i
-0.3292	0.1156 - 0.0723i	0.1156 + 0.0723i	0.1425	-0.1165	-0.0095	0.2294 - 0.1393i	0.2294 + 0.1393i
-0.3346	-0.2610 + 0.0107i	-0.2610 - 0.0107i	-0.1114	-0.4710	0.5910	0.6706	0.6706
-0.3721	-0.5092	-0.5092	0.1782	0.2410	0.6347	-0.0326 + 0.0750	-0.0326 - 0.0750i
-0.3773	0.3195 - 0.0977i	0.3195 + 0.0977i	0.0262	-0.2859	0.1127	-0.0390 - 0.0018i	-0.0390 + 0.0018i