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Identification of Biometrics Using Fingerprint Minutiae Extraction Based on Crossing Number Method

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Abstract

Abstract Biometrics based on fingerprint images is a self-recognition technique using fingerprint to represent a person's identity. Fingerprint is characteristic of someone's identity precisely and safely because there are no similarities and cannot be falsified. The purpose of this research is to develop a biometrics identification system based on fingerprint images by utilizing a cell phone camera for the acquisition of fingerprint images. This is based on its simplicity because almost everyone has a cell phone so that a person's identification system based on fingerprint can be used anytime and anywhere. The research was conducted using images generated from cell phone cameras with camera specifications of 2, 5 and 8 mega pixels. The method used in image processing consists of the minutiae crossing number method for the feature extraction process and the minutiae based matching method for the similarity measurement process. The results of the research concluded that cell phone cameras with specifications of 5 and 8 mega pixels can be used for the process of image acquisition in biometrics systems based on fingerprint. The feature extraction process of image results using the minutiae crossing number method and the match measurement process using the minutiae based matching method resulted in an accuracy value of 92.8% on a 5 mega pixel camera and 95.3% on an 8 mega pixel camera. The accuracy value depends on the results of the image acquisition stage, pre-processing, the threshold value in the identification process, and the number of images used in the training data in the database.

Keywords: *Identification; biometrics; fingerprint; minutiae; cell phone*

1. Introduction

Biometric systems have been used before human recognize and use computer in their activities. These systems make use of the physical or biologycal traits of human beings for recognition and authentication purposes [10]. Fingerprint, iris, and face are the most common biological traits of humans used in this system. Biometric systems fulfills two important functions, namely identification and verification. The identification system aims to break a person's identity while the verification system aims to reject or accept an identity claimed by someone [13]. One of biometrics technology is fingerprint biometrics, a self-recognition system using fingerprint to represent someone's identity [7]. Fingerprint have universal, unique, permanent and collectability properties.

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That is, each person has a fingerprint with different characteristics, does not change over a long period of time and its characteristics are easily obtained and measured quantitatively. Fingerprint is difficult to duplicate or counterfeit, cannot be used simultaneously and cannot be forgotten like the use of a password in a self-recognition system that requires users to remember [17]. Therefore, fingerprint is used in biometrics technology to create systems that are able to recognize a person's identity precisely and safely because the system is not easily fooled.

After going through the preprocessing, minutiae extraction, and postprocessing stages of the fingerprint image captured from the scanner, the verification results show the average accuracy of the fingerprint image validation on database is 37,79%, meaning that more than 60% of manual validation minutiae cannot be use to verify the authenticity of fingerprint [5]. In contrast to the research of Sajati et al., the image being tested is the result of a fingerprint stamp using black ink affixed to a piece of paper. Then the fingerprint visible on the paper is photographed one by one according to the group and owner of the fingerprint image. The average value of the accuracy of the fingerprint image minutiae validation is 63%, thus showing poor results [9].

The fingerprint image in this study was generated from a smartphone camera by bringing the fingerprint closer to the camera with an unknown distance specification. The methods used in this study is the minutiae extraction method with the concept of crossing number for the feature extraction process and the minutiae based matching method for fingerprint matching. This study aims to test the accuracy of the validation of minutiae extraction results using the crossing number method and the minutiae based matching method on the extraction results manually.

2. Methods

2.1. Biometrics

Literally, the term biometrics is derived from words bio meaning "connected with life and living things" and metrics meaning "to measure" [4]. Biometrics refers to the measurement and statistical analysis of people's unique physical and behavioral characteristics [11]. Biometrics based on physiological/ physical characteristics uses the physical parts of a person's body as a unique code for recognition, such as DNA, ears, heat traces on the face, hand geometry, facial hand vessels, fingerprint, iris, palm, retina, teeth, and smell from body sweat. Biometrics based on behavioral characteristics uses the person's behavior as a unique code for recognition, such as gait, keystrokes, signature, and voice [6]. The biometrics system will automatically recognize a person's identity based on a biometric feature by matching it to the biometrics characteristics stored in the database. The biometrics system as an authentication system is able to decide whether the recognition result is valid or invalid, accepted or rejected, recognized or not recognized.

2.2. Fingerprint

Fingerprint can be used as an identification system that can be used in the application of information technology such as security access system and authentication system because fingerprint have the following characteristics: 1) Perennial Nature, meaning scratches on fingerprints that stick to human skin for life, 2) Immutability, meaning a person's fingerprints never change, unless they get into a serious accident, 3) Individuality, meaning fingerprints pattern is unique and different for each person [13]. The unique characteristics of fingerprint are formed by the ridge and valley patterns. Ridge is defined as a single curved segment that protrudes from the surface. Valley is the area between two adjacent ridges [14]. An example of a fingerprint image acquired by a scanner can be seen in Figure 1. The black line shows the ridge and the white line shows the valley.

Figure 1. Fingerprint Image

2.3. Minutiae Extraction

The feature that will be taken from the fingerprint image data is the minutiae, which are the points formed by the skin ridges on the fingerprint. There are about 150 types of minutiae which are categorized based on their configuration [12]. Figure 2 shows the minutiae types in a fingerprint

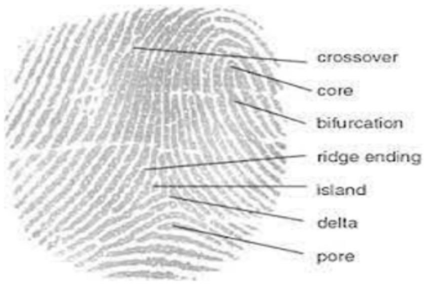
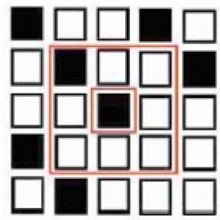
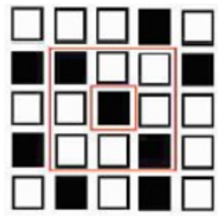
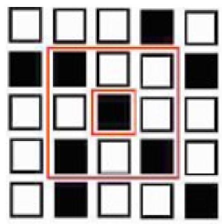


Figure 2. Fingerprint Image

Minutiae is often used as a research basis to identify a person's fingerprint. The minutiae location and the minutiae angles are derived after minutiae extraction [3]. Minutiae extraction from thinned image using crossing number concept. Crossing Number is defined as half of the sum of differences between intensity values of two adjacent pixels [14]. Table 1 shows crossing number and type of minutiae.

The crossing number technique algorithm can cancel the incorrect minutiae value with the configuration of the ridge pixels connected to the minutiae points to validate the minutiae extraction results by following rules: 1) if a branch has more than 2 branches and the length is less than the specified threshold, then the pixel is not marked as a bifurcation, 2) if there is a short fault (the distance between the fault and other neighbors is not more than 1 pixel) than the pixel is not marked as a ridge ending, 3) if many minutiae (bifurcation or ridge ending) are found in one adjacent area (cluster), then delete all the minutiae, but leave one minutiae closests to the center point of the area, 4) if minutiae is found facing each other and there is no ridge limiting it, then delete the minutiae [15].

Table 1. Crossing Number and Type of Minutiae

Crossing Number	Points	Type of Minutiae
1		Ridge ending point
2		Continuing ridge point
3		Bifurcation point

2.4. Minutiae Matching

Minutiae matching is the process of calculating the match score between the minutiae extraction data on the test image and the minutiae extraction results stored in the database using the minutiae based matching method. The matching process using the minutiae based matching method through 4 stages, including comparison of pairwise similarity, juxtaposition, adjustment, and scoring [16].

1. Comparison of pairwise similarity
   Two fingerprint images are aligned by sliding and rotating the fingerprint images so that the two fingerprints overlap each other according to their minutiae type. Minutiae data to be matched is represented as:
   $$T = [x \quad y \quad \theta \quad CN] \tag{1}$$
   where x, y, θ and CN are the coordinates (axis) of the fingerprint point, orientation angle, and crossing number to indicate the point as a ridge ending or ridge bifurcation. To align minutiae data, a translation process is needed by assuming all minutiae as:
   $$T_i = [x_i \quad y_i \quad \theta_i \quad CN_i]^T \tag{2}$$
   and the minutiae coordinate reference is assumed as:
   $$T_i' = [x_i' \quad y_i' \quad \theta_i' \quad CN_i']^T = B_i * R \tag{3}$$
   If two fingerprint images have the same type of minutiae, then the transformation process follows the equation:
   $$T_i' = [x_i' \quad y_i' \quad \theta_i' \quad CN_i']^T = \begin{pmatrix} x_i - x_{Ref} \\ y_i - y_{Ref} \\ \theta_i - \theta_{Ref} \\ CN_n \end{pmatrix}^T * \begin{bmatrix} \cos\theta_{Ref} & \sin\theta_{Ref} & 0 & 0 \\ -\sin\theta_{Ref} & \cos\theta_{Ref} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \tag{4}$$

where T_i' is data minutiae after transformation.

2. Juxtaposition
One of the fingerprint images is then transformed by rotation to optimize the alignment between the two minutiae data for the minutiae matching process. Juxtaposition process using following equation:

$$T_i'' = [x_i' \quad y_i' \quad \theta_i' \quad CN_i']^T = \begin{pmatrix} x_i' - 0 \\ y_i' - 0 \\ \theta_i' - \theta_{Ref} \\ CN_n' \end{pmatrix}^T * \begin{bmatrix} \cos\theta_{Ref} & \sin\theta_{Ref} & 0 & 0 \\ -\sin\theta_{Ref} & \cos\theta_{Ref} & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

where T_i'' is data minutiae after transformation

$$\theta_{Ref} = \frac{a * pi}{180} \quad (6)$$

where a is rotation index from -5 to 5.

3. Adjustment
The adjustment process uses T' data in the first image and T'' in the second image. Comparison between point distance (sd = spatial distance) and difference in minutiae orientation values (dd = direction difference) using equations 7 and 8.

$$sd(m_i', m_j) = \sqrt{(x_i' - x_i)^2 + (y_i' - y_i)^2} \leq r_0 \quad (7)$$

$$d(m_i', m_j) = \min(|\theta_i' - \theta_j|, 360^0 - |\theta_i' - \theta_j|) \leq \theta_0 \quad (8)$$

4. Scoring Scoring is represented by calculating the similarity score between two fingerprint images based on the number of minutiae points that are considered the same. The fingerprint similarity score (S) can be calculated by equation 9.

$$similarity(s) = \sqrt{\frac{(n\ Mathed)^2}{(n\ first\ image) \times (n\ second\ image)'}} \quad (9)$$

where n is number of minutiae points.

3. Materials and Methods

3.1. Materials

The materials used in this study include fingerprint images that were acquired using cellular phone camera, laptop, cellular phone, and Matlab R2017a software.

3.2. Methods

The stages of research that aims to test the accuracy of identification of fingerprint images originating from cell phone camera using minutiae method is shown in Figure 3.

3.2.1. Fingerprints Image Acquisition

Fingerprint image acquisition using a mobile phone camera specification of 5 and 8 Mega Pixels (MP). The index finger is brought to the cell phone camera with a distance of 6 cm to 8 cm and then photographed using a flash. Fingerprint image of 15 people were collected and 750 images were obtained. For the developed system testing requirements, 200 fingerprint images were obtained from 15 people based on the composition of 5 people with 10 images each used as negative image test data and 10 people with 15 images each used as training and testing data for positive images. A positive image is an image that comes from the same

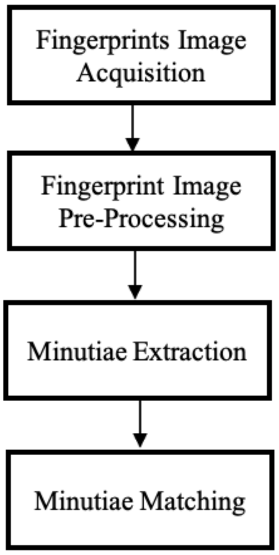


Figure 3. Work Flow Diagram of Fingerprint Biometrics Identification System

subject (person) and is compared with one of the images from the training data, while a negative image is an image that comes from the different subject (person) and is compared with one of the images from the training data. For the system accuracy testing requirements, 550 fingerprint images were obtained from 15 people based on the composition of 5 people with 15 images each used as negative image test data and 10 people with 20 images each used as training and testing data for positive images.

3.2.2. Fingerprint Image Pre-Processing

Pre-processing is the stage to normalize the results of the fingerprint image acquisition. Pre-processing consists of sequential processing stages: image cropping, grayscale conversion, image improvement, binary image conversion, and thinning [1].

3.2.3. Minutiae Extraction

Minutiae extraction using Crossing Number technique to determine ridge ending and ridge bifurcation [13]. Ridge ending and ridge bifurcation are the types of minutiae that will be used as a feature of the fingerprint in this study. The ridge ending is the location where a ridge comes to an end and the ridge bifurcation is the location where a ridge divides into two separate ridges. Minutiae extraction results will be processed to eliminate minutiae points according to the deletion rules.

3.2.4. Minutiae Matching

Minutiae extraction results of the test data images were matched with the minutiae extraction results of training data that were previously available in database. Minutiae matching using minutiae based matching method [12]. The calculation of the similarity score uses equation 1 to 9.

3.3. Results

3.3.1. Image Acquisition

The process of capturing fingerprint images by placing one finger in front of the rear camera of the cellphone. Figure 4 shows the results of fingerprint images taken using a mobile phone camera specification of 5 MP and 8 MP with flash in a room with bright lighting condition. The finger used in this study was the index finger of the left hand. The index finger is faced in front of the cellphone camera with the fingerprint area facing straight ahead and the index finger positioned towards the right of the body. Based on the experimental results, images captured using 5 MP and 8 MP camera specifications can be used for fingerprint identification data with the recommended distance of 6 to 8 cm. The image acquisition process is related to the accuracy in capturing fingerprint image and the results of the acquisition can affect the results of the image cropping process. The right image capture process is to use a flash and the fingerprint position is symmetrically straight.

3.3.2. Pre-Processing

The results of the fingerprint image acquisition are then cropped by utilizing the segmentation results to get the expected image. The method used in segmentation is the clustering method with the k-Means Algorithm [14]. Grayscale conversion is the process of converting an image with an RGB color orientation into an image with a gray orientation. This process is implemented using the rgb2gray function in the matlab software. The unique characteristics of fingerprint are formed by the ridge and valley patterns. Binarization is the process that converts a grey level image into a binary image. This improves the contrast between the ridges and valleys in a fingerprint image, and consequently facilitates the extraction of minutiae [8]. Thinning is a morphological operation that successively erodes away the foreground pixels in binary image until they are one pixel wide [6]. A standard thinning algorithm is employed, which performs the thinning operation using two subiterations. This algorithm is accessible in matlab software via the 'thin' operation under the bwmorph function. Figure 5 shows the result of fingerprint image pre-processing.

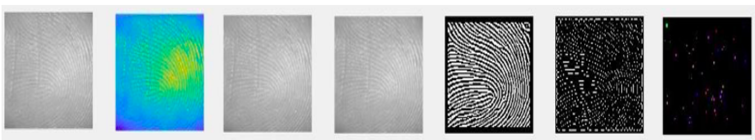


Figure 4. The Results of Fingerprint Image Pre-Processing

3.3.3. Minutiae Extraction

Figure 6 shows the results of minutiae extraction using the crossing number technique on one of the test image files. Figure 7 shows the results of minutiae extraction using the crossing number technique on one the training image files.

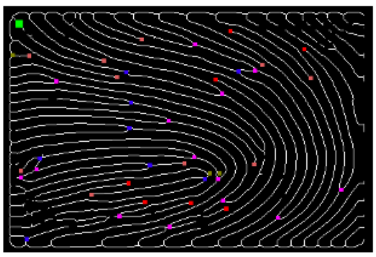


Figure 5. Minutiae Extraction Result of The Test Image

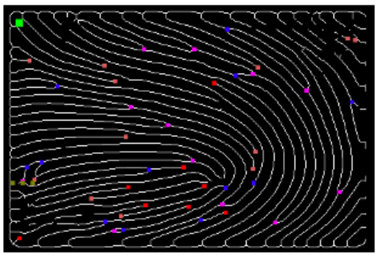


Figure 6. Minutiae Extraction Result of The Training Image

3.3.4. Minutiae Matching

The minutiae matching process requires minutiae extraction data from test images to be matched to each minutiae extraction result from training data that was previously available in database. Table 2 shows the minutiae extraction data on the test image and Table 3 shows the minutiae extraction results stored in the database.

Through the fingerprint identification process using the minutiae based matching method, the test image similarity score was obtained for each training data. The highest similarity score is then compared with the identification threshold value. If the highest similarity score is more than 0.3000, then the test image has been identified and the selected training image is the image that has the highest score. Meanwhile, if the highest score is less than 0.3000 then the test image is considered unidentified [2]. Figure 8 shows the results of overlay and minutiae matching from the minutiae extraction result in Figures 6 and 7 with a similarity score of 0.65932.

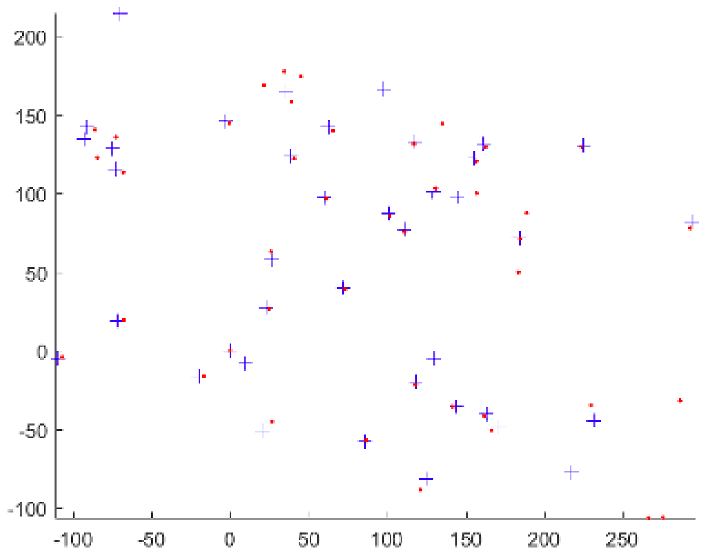


Figure 7. The Results of Overlay and Minutiae Matching

3.4. Discussion

The dimensions of images used in the experiment are 250x167 pixel, 350x232 pixel, and 450x302 pixel. Based on the experimental results, image dimensions have an effect on minutiae extraction, similarity score, and computation time. If the image dimensions are larger, the more minutiae points have been extracted, the value of similarity score is getting smaller both using positive or negative image, and computation time is getting slower.

The threshold value is the tolerance value used in the process of identification and data matching. The threshold value that have been determined through trial and error are 10, 12, 14, and 16. Effect of threshold value on positive and negative images with image dimension of 450x302 pixel is shown in Table 4 and Table 5.

The threshold value used in the matching process affects the similarity score and computation time. If the threshold value is higher, the false accept rate will increase and the false reject rate will decrease. Conversely, if threshold value is lower, the false accept rate will decrease and the false reject rate will increase. Meanwhile, based on the computation time, if the threshold value is higher, the literacy process will increase and computation time will be longer.

Based on the experimental results to determine the effect of the amount of training data on the accuracy of the system, it was concluded that if the amount of training data is more, then the value of system accuracy will be higher. This has been proven by the use of training data as many as 10 images, then the accuracy value from the results of the confussion matrix calculation is 84%. When using training data as many as 20 images, the accuracy value is 92.7% and 93,3% when using training data as many as 30 images.

4. Conclusion

The use of cell phone cameras for the process of image acquisition in biometrics identification based on fingerprints can be used as a new alternative to recognize someone's identity based on fingerprints.The use of the crossing number method for feature extraction and the minutiae based matching method for match measurements in fingerprint biometrics identification has a system accuracy value of 92.8% using a fingerprint image captured with a 5 MP cell phone camera and 95.11% using fingerprint images captured with a 8 MP cell phone camera. The success rate of biometrics identification based on fingerprints depends on how to capture the image during the image acquisition process, the image quality of the pre-processing results, the number of training data, and the value of the threshold.

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