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Template Matching Analysis using Neural Network for Mobile Iris Recognition System

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Abstract. Today, the use of mobile phone among individuals with an advanced technology, acquisition and computation resources is crucial in securing personal data and services as well as in identifying a person. Furthermore, there has been growing interest of researchers using mobile as an acquisition device to capture an eye image in a non-cooperative environment (static motion and at different distances) for iris recognition. However, the use of mobile as an acquisition device still facing some noise factors because the quality of image captured in this environmental condition is low compared to a camera device. Besides, low awareness of user in handling the mobile devices and lack technical experiences in capturing iris images with this environmental condition is generally uncontrolled contribute to producing unpredictable low quality of eye images. Due to these issues, it led to incorrect segmentation of iris boundaries and subsequently lowered the ability to match the iris features. Hence, this condition contributes to performance degradation of iris recognition system. Therefore, to improve the ability to match the iris features in mobile iris recognition system, a combination with neural network is proposed. The iris database used to test against these methods is CASIA-Iris-M1-S2. The proposed method, a combination of Hamming distance and neural network has achieved a better result where it increases the existing method in term of accuracy for mobile iris recognition under non-cooperative environment.

Keywords: Mobile iris, Template Matching, Neural Network, Non-Cooperative Environment.

1. Introduction
Latest technology has been widely used in electronic devices especially in mobile [1]. Besides, mobile devices are widely known in term of portability and flexibility for different tasks [2]. However, many issues related to security flaw have been identified in mobile devices [3]. The demand of secure data and services led to the development of biometric recognition systems on mobile devices. One of the largest deployed application of biometric technologies is fingerprint [4].

Although the touch-based sensing interface in fingerprint biometric is very convenient, but the hygienic problems on the sensor surface causes users to avoid use of this technology. Besides, the existence of foreign elements on the sensor surface and the small sized sensors has degraded the performance of fingerprint biometric on mobile devices. Moreover, according to [5], the fingerprint recognition system was vulnerable to fake fingerprints in mobile device. The reliability of iris
recognition system has increased the interest to integrate this technology in mobile devices because this technology uses a touchless sensor and non-intrusive to the fake iris [6]. Besides, this technology is reliable to visual recognition of a person's when imaging is captured at distances of less than a meter [7,8]. However, the integration of this technology with mobile device can be degraded due to low central processing unit in mobile device, user’s gazing point and existence of noises such as motion-blurred, occlusion of eyelids and specular reflection. Hence, to improve the ability to match the iris in mobile iris recognition system, a method of neural network is suggested.

2. Literature Review

Template matching is a continuous step of iris recognition after feature extraction. During template matching process, the templates obtained from feature encoding requires a matching metric which it measures a similarity between two iris templates. The metric will produce a range of value when two iris templates from the same eye image known as intra-class while another range of value generated from two different irises is called as inter-class. From these templates, distinct and separate value should obtain in order to make decision either the two templates are from two different irises or same iris.

Various template matching methods such as Hamming distance, weighted Euclidean distance (WED) and normalised correlation has been proposed to measure the eye template. Hamming distance provides a degree of dissimilarity bits between two equal lengths of binary patterns. The integrodifferential operator (IDO) locates inner and outer circle of iris and use Hamming distance techniques to calculate the matching of two templates [9]. Past researchers had addressed that HD provides better performances in iris recognition system and it is a fast and simple technique [10]. Besides, it also adaptable as many image data types has been tested by using HD such as twin image, noisy image and non-cooperative image. A new technique has been proposed in template matching which is hybrid of fragile bit distance with HD and measures the accuracy to the HD technique alone [11]. It used in twin iris data and the proposed techniques gives promising results.

The WED derived from old Pythagoras theorem which is defined as linear distance between two points in the dimensional space. It used mostly to compare two different templates especially if the templates are composed of integer values. WED also is the commonly technique has been used when its related dealing with distance as it can have from one up to n-dimensional spaces. Two researchers have addressed the advantages of WED performance in iris recognition system. According to [12], the WED is very compatible to be embedded with classification technique to produce higher accuracy and WED is the simple techniques since the equation of this technique is only repeated Pythagoras theorem formula. This method was used by [13] with wavelet transform and multi-channel Gabor filtering to represent the iris texture. This system proves by using that method, accuracy rate reach 93.8% [11].

However, computational involved in determining distance is very complex and according to [14], it requires a lot of calculation process and requires massive computation process. Wildes has been used normalized correlation between the acquired and database representation for goodness of match. This technique has advantageous over standard correlation as it able to account the local in image intensity that corrupt the standard correlation calculation.

3. Mobile Iris Dataset: CASIA-Iris-M1-S2

This database is divides into three different distances which are 20cm, 25cm and 30cm. For each distance, 10 images were captured so that each person contributes to 30 images. Table 1 presents eye images in this dataset.
Table 1. Mobile Iris Dataset: CASIA-Iris-M1-S2.

| Distance | Eye Images |
|----------|------------|
| 20 cm    | ![Image](image1) ![Image](image2) ![Image](image3) |
| 25 cm    | ![Image](image4) ![Image](image5) ![Image](image6) |
| 30 cm    | ![Image](image7) ![Image](image8) ![Image](image9) |

4. Methodology

Figure 1 presents the research framework. Circular Hough transform is a common algorithm that used to detect and determine simple geometric shape of an objects such as lines, circles, curves which present in the image. Circular HT is used to infer radius and centre coordinates of the pupils and iris regions [1]. Pre-processing has been done before the iris segmentation process. Degradation in segmentation accuracy normally caused due to low contrast of between pupil and iris [15]. Thus, before proceed to iris segmentation process, contrast enhancement is required to overcome this issue. Segmentation process started with limbic and continuously followed by pupillary boundaries. Firstly, calculate derivatives of intensity values of an eye image by generated an edge map, then thresholding the result of it. Binary edge map is then analysed on HT space to determine three parameters of one circle which is \((h_{o}, k_{o}, \text{Rad})\). Circular HT formula is shown below:

\[
HT(h_{o}, k_{o}, \text{Rad}) = \sum_{j=1}^{n} (h_{n}, k_{n}, h_{o}, y_{o}, \text{Rad})
\]

where \((h_{o},k_{o})\) is a line pixel and \(HT(h_{o},k_{o},h_{o},k_{o},\text{Rad})\) equal to 1 if \((h_{o},k_{o})\) is on circle and 0 if otherwise. Location of \((h_{o},k_{o},\text{Rad})\) with maximum value of \(HT(h_{o},k_{o},\text{Rad})\) has been chosen as a parameter vector for strongest circular boundary while \(j\) equal to 1 to \(n\). Process of segmentation ends with eyelashes and eyelid removal of an iris image by using linear HT and thresholding algorithm.
Next process after segmentation has been done is normalization. Normalization of an eye image is needed in order to transform the iris region to a fixed dimensions for allowing comparisons to happen. This process will produce iris regions that having same constant dimensions so that two eyes images will of same iris will having characteristics features at same spatial location. For normalization method, Daugman's Rubber Sheet (DRS) techniques was chosen. This techniques remaps each point to a pair of polar coordinates $(r, \theta)$ as $r$ is on the interval $[0,1]$ and $\theta$ is an angle $[\theta, 2\pi]$. Remapping of iris region from $(x,y)$ on Cartesian coordinates to the normalised a non-concentric polar representation is modelled as follow;

$$I(x(r,\theta),y(r,\theta)) \rightarrow I(r,\theta)$$  \hspace{1cm} (2)

with

$$s(r,\theta) = (1-r)x_p(\theta),$$

$$y(r,\theta) = (1-r)y_p(\theta) + ry_l(\theta)$$

where $I(x,y)$ is the iris region image, $(x,y)$ is the original Cartesian coordinates, $(r,\theta)$ is the corresponding normalised polar coordinates and $x_p$, $y_p$ and $x_l$, $y_l$ refer to coordinates of the pupil and iris boundaries along the $\theta$ direction.

Feature extraction provide accuracy to iris recognition process when the feature of iris were extracted. For this research study, one dimensional of log Gabor filter has been used. The formula of log Gabor filter is shown as follow:

$$L_GB(h) = exp((-\log(h/h_0))^2/2(\log(\sigma h_0))^2).$$  \hspace{1cm} (3)

where $h_0$ is the centre frequency and $\sigma$ is the bandwidth of the filter.

In order to determine the uniqueness of iris patterns, the value of Hamming Distance (HD) need to be obtained by comparing the templates of two different eyes. Thus, the result of distribution HD were examined. HD acts as a matching algorithm where two of different templates is compared to get the number of bits. By using HD, capability to determine either the two patterns of iris templates were generated by the same iris or from two different irises. Hamming distance is described as the total of exclusive-OR between X and Y divided by N, where N is the total number of bits in bit pattern. The formula of Hamming Distance as follow:

$$HD = \frac{1}{N} \sum_{j=1}^{N} X_j \text{ (XOR)} \ Y_j$$  \hspace{1cm} (4)
Each individual iris region has contained feature with high degrees of freedom, it will produce a bit pattern that is independent with another iris region. This means, it will highly correlated if the two iris codes produced from the same iris. Hamming Distance between two patterns is equal to 0.5 if the iris template was generated by two different irises. While if the two templates are from the same iris, the value of Hamming Distance should be nearer to 0.0 as they are highly correlated and the bits between two iris code should be agree.

Designing the neural network model is the important step in the implementation phase. In this step, elements such as input nodes and output nodes are determined. The hamming distance was set as an input while targeted output was set as an output for this model. Ideal output calculated from the neural network will be used to measure the error rate and mean square and back-propagation is used to train the model.

5. Analysis and Results
By using HD, capability to determine either the two patterns of iris templates were generated by the same iris or from two different irises. Each individual iris region has contained feature with high degrees of freedom, it will produce a bit pattern that is independent with another iris region. This means, it will highly correlated if the two iris codes produced from the same iris. Hamming Distance between two patterns is equal to 0.5 if the iris template was generated by two different irises. While if the two templates are from the same iris, the value of Hamming Distance should be nearer to 0.0 as they are highly correlated and the bits between two iris code should be agree.

In this research, the output data get from the ANN was used to calculate FRR, FAR and the accuracy of mobile iris recognition. FRR is defined as measures the probability the enrolled individual not been identifies while FAR defined as the measure of the probability in the biometric system is not correct which mean the system can successfully accept attempt by an authorized user. Below shows the formula of FRR, FAR and the accuracy of mobile iris recognition.

5.1. Accuracy of Mobile Iris Recognition For Left and Right Sides
Table 2 show the accuracy of mobile iris recognition for left and right eye sides. For left eye side, at threshold value of 0.05, the accuracy of mobile iris recognition is 99.63% where it is the highest accuracy among all and at threshold value of 0.15, accuracy of mobile iris recognition decreases to 99.59%. When threshold value is 0.25, the accuracy of mobile iris recognition is 99.48% while at threshold value of 0.35, the value of accuracy is 99.31%. Accuracy of mobile iris recognition is 99.11% where it is the lowest among all where the threshold value is set to 0.45.

For right eye side, at threshold value of 0.05, the accuracy of mobile iris recognition is 99.75% where it is the highest accuracy among all and at threshold value of 0.15, accuracy of mobile iris recognition decreases to 99.69%. When threshold value is 0.25, the accuracy of mobile iris recognition is 99.56% while at threshold value of 0.35, the value of accuracy is 99.36%. Accuracy of mobile iris recognition is 99.11% where it is the lowest among all where the threshold value is set to 0.45.

Based on the calculation result, it can be concluded that as the threshold value nearer to 0.5, the accuracy of mobile iris recognition was decreased while as the threshold nearer to 0, the accuracy of mobile iris recognition increased. This is due to the two templates were generated from the different irises when the value of threshold nearer to 0.5 while when it is nearer to 0, it is mean that the two templates were generated from the same iris.
Table 2. Accuracy of mobile iris recognition for left eye side.

| Threshold | FAR (%) | FRR (%) | Accuracy (%) | FAR (%) | FRR (%) | Accuracy (%) |
|-----------|---------|---------|--------------|---------|---------|--------------|
| 0.05      | 0.0264  | 0.7167  | 99.63        | 0.0306  | 0.4704  | 99.75        |
| 0.15      | 0.0247  | 0.8049  | 99.59        | 0.0279  | 0.6016  | 99.69        |
| 0.25      | 0.0200  | 0.8600  | 99.56        | 0.0240  | 0.8590  | 99.56        |
| 0.35      | 0.0100  | 1.2600  | 99.36        | 0.0160  | 1.2590  | 99.36        |
| 0.45      | 0.0005  | 1.7826  | 99.11        | 0.0043  | 1.7784  | 99.11        |

Table 3 shows the accuracy of mobile iris recognition of the proposed method. At threshold value of 0.05, the accuracy of mobile iris recognition is 99.36% where it is the highest accuracy among all and at threshold value of 0.15, accuracy of mobile iris recognition decreases to 99.00%. When threshold value is 0.25, the accuracy of mobile iris recognition is 98.88% while at threshold value of 0.35, the value of accuracy is 98.53%. Accuracy of mobile iris recognition is 98.05% where it is the lowest among all where the threshold value is set to 0.45.

Table 3. Accuracy of mobile iris recognition of the proposed method.

| Threshold | FAR (%) | FRR (%) | Accuracy (%) |
|-----------|---------|---------|--------------|
| 0.05      | 0.1955  | 1.0900  | 99.36        |
| 0.15      | 0.1580  | 1.8400  | 99.00        |
| 0.25      | 0.1455  | 2.0900  | 98.88        |
| 0.35      | 0.1080  | 2.8400  | 98.53        |
| 0.45      | 0.0043  | 3.8400  | 98.05        |

According to [10], the best technique result is when low FRR, low FAR and high accuracy was obtained from the comparisons of techniques. From the result obtained to compare Hamming distance and Euclidean distance, value of FRR for Hamming distance is 2.5% while Euclidean distance is 8.75%. For value of FAR, Hamming distance is 8.75% while Euclidean is 12.5%. Table 4 shows the summarize accuracy of the existing and the proposed methods. From the table, it can be conclude where the proposed method combination of Hamming distance and Artificial neural network has the lowest value of FAR which is 0.12% and the lowest value of FRR which is 2.34% which lead to the highest accuracy among the other techniques with value of 98.77%.

Table 4. Summarization accuracy of the existing and the proposed methods.

| Methods                              | FAR (%) | FRR (%) | Accuracy (%) |
|--------------------------------------|---------|---------|--------------|
| Hamming Distance                     | 8.75    | 2.50    | 96.48        |
| Euclidean Distance                   | 12.50   | 8.75    | 93.35        |
| **Hamming Distance + Artificial Neural Network (This Study)** | **0.12** | **2.34** | **98.77** |
6. Conclusion
The proposed method which is combination of Hamming distance and Artificial neural network has provided good results to match unique iris feature of eyes compared to existing method such as Hamming distance and Euclidean distance method. This is because of the value of FAR and FRR of proposed method gave the lowest value and thus increased the accuracy of mobile iris recognition. Analysis from the graph of equal error rate between Hamming distance and combination of Hamming distance and Artificial neural network showed that there is no intersection between them. This is due to the value of FAR and FRR for both methods did not equal. As a conclusion, from the experimental result of those two methods it proofed that the proposed method of this research study has gave an enhancement in term of accuracy for mobile iris recognition by using a dataset under non-cooperative environment.

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