FEATURE EXTRACTION USING TWO DIMENSIONAL (2D) LEGENDRE WAVELET FILTER FOR PARTIAL IRIS RECOGNITION

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This thesis is dedicated to my beloved parents.

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ABSTRACT

An increasing need for biometrics recognition systems has grown substantially to address the issues of recognition and identification, especially in highly dense areas such as airports, train stations, and financial transactions. Evidence of these can be seen in some airports and also the implementation of these technologies in our mobile phones. Among the most popular biometric technologies include facial, fingerprints, and iris recognition. The iris recognition is considered by many researchers to be the most accurate and reliable form of biometric recognition because iris can neither be surgically operated with a chance of losing slight nor change due to aging. However, presently most iris recognition systems available can only recognize iris image with frontal-looking and high-quality images. Angular image and partially capture image cannot be authenticated with the existing method of iris recognition. This research investigates the possibility of developing a technique for recognition partially captured iris image. The technique is designed to process the iris image at 50%, 25%, 16.5%, and 12.5% and to find a threshold for a minimum amount of iris region required to authenticate the individual. The research also developed and implemented two Dimensional (2D) Legendre wavelet filter for the iris feature extraction. The Legendre wavelet filter is to enhance the feature extraction technique. Selected iris images from CASIA, UBIRIS, and MMU database were used to test the accuracy of the introduced technique. The technique was able to produce recognition accuracy between 70 – 90% CASIA-interval with 92.25% accuracy, CASIA-distance with 86.25%, UBIRIS with 74.95%, and MMU with 94.45%.

ABSTRAK

Perkembangan dalam keperluan yang semakin meningkat untuk sistem pengiktirafan biometrik telah meningkat dengan ketara untuk menangani isu-isu pengiktirafan dan pengenalan terutamanya di kawasan yang sangat padat seperti lapangan terbang, stesen kereta api dan transaksi kewangan. Kesimpulannya dapat dilihat di beberapa lapangan terbang dan juga pelaksanaan teknologi ini di dalam setiap telefon bimbit masa kini. Antara teknologi biometrik yang paling popular termasuk muka, cap jari dan pengiktirafan iris. Pengiktirafan iris dianggap tepat oleh banyak penyelidik untuk menjadi pengiktirafan biometrik yang paling tepat dan boleh dipercayai, kerana iris tidak boleh dibedah secara surgikal kerana boleh mengakibatkan kehilangan pandangan atau perubahan kerana penuaan. Walau bagaimanapun, pada masa ini kebanyakan sistem pengiktirafan iris yang ada hanya boleh mengiktiraf imej iris dengan imej yang berwawasan depan dan berkualiti tinggi. Imej sudut dan imej pengambil sampel sebahagiannya tidak dapat disahkan dengan kaedah pengenalan iris sedia ada. Penyelidikan ini menyiasat kemungkinan yang boleh membangunkan teknik untuk pengiktirafan sebahagian imej iris yang ditangkap. Teknik ini direka untuk memproses imej iris pada 50%, 25%, 16.5% dan 12.5% dan untuk mencari ambang untuk jumlah minimum iris yang diperlukan untuk mengesahkan individu. Penyelidikan ini juga membangun dan melaksanakan penapis wavelet Dua Dimensi (2D) Legendre untuk pengekstrakan ciri iris. Penapis wavelet Legendre adalah untuk meningkatkan teknik pengekstrakan ciri. Imej iris yang dipilih dari pangkalan data CASIA, UBIRIS dan MMU digunakan untuk menguji ketepatan teknik yang diperkenalkan. Teknik ini dapat menghasilkan ketepatan pengiktirafan antara 70-90% CASIA-selang dengan ketepatan 92.25%, jarak CASIA dengan 86.25%, UBIRIS dengan 74.95% dan MMU dengan 94.45%.

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LIST OF SYMBOLS AND ABBREVIATIONS

θ_j	-	Bias for the jth unit.
η	-	Learning rate
α	-	Momentum coefficient
$a_{net,j}$	-	Net input activation function for the jth unit.
a_1	-	BPGD
a_2	-	BPGD-AG
a_3	-	BPGD-AGAMAL
c	-	Gain of the activation function
e	-	Exponent
$f(x)$	-	Function of x
f	-	The squashing or activation function of the processing unit
o_i	-	Output of the ith unit
o_j	-	Output of the jth unit
o_k	-	Output of the kth output unit
t_k	-	Desired output of the kth output unit
w_{ij}	-	Weight of the link from unit i to unit j
w_{jk}	-	Weight on the link from node j to k
$x < 0$	-	x is less than 0
$x > 1$	-	x is greater than 1
$x \geq 0$	-	x is greater than or equal to 0
$-1 \leq x \leq 1$	-	x is greater than or equal to -1 and x is less than or equal to 1
A	-	All algorithms

E	-	Error function
H	-	Performance of the BPGD-AGAMAL against BPGD on measuring criteria
J	-	Performance of the BPGD-AGAMAL against BPGD-AG on measuring criteria
K	-	Improvement ratio of the BPGD-AGAMAL against BPGD on measuring criteria
LB	-	Lower bound
M	-	Improvement ratio of the BPGD-AGAMAL against BPGD-AG on measuring criteria
N	-	Performance of BPGD on measuring criteria
Q	-	Performance of BPGD-AG on measuring criteria
R	-	Performance of BPGD on measuring criteria
UB	-	Upper bound
ADALINE	-	Adaptive Linear Element
AI	-	Artificial Intelligence
ANN	-	Artificial Neural Network
BP	-	Back Propagation
BPGD	-	Back Propagation Gradient Descent
BPGD-AG	-	Back Propagation Gradient Descent with Adaptive Gain
BPGD-AGAMAL	-	Back Propagation Gradient Descent with Adaptive Gain, Adaptive Momentum and Adaptive Learning Rate
CPU	-	Central Processing Unit
GD	-	Gradient Descent
IWS	-	Initial Weight Selection
MLFNN	-	Multilayer Feed forward Neural Network
MLP	-	Multilayer Perceptron
MSE	-	Mean Squared Error
NN	-	Neural Network
OBP	-	Optical Back Propagation
RBF	-	Radial Basis Function

SD	-	Standard Deviation
SPLNN	-	Single Layer Perceptron Neural Network
UCIMLR	-	University California Irvine Machine Learning Repository

LIST OF PUBLICATIONS

Danlami, M., Jamel, S., Ramli, S. N., & Deris, M. M. (2019). A Framework for Partial iris recognition based on Legendre Wavelet Filter. (IJACSA) *International Journal of Advanced Computer Science and Applications*, 10(5), 36–41.

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CHAPTER 1

INTRODUCTION

1.1   Background of Study

The increasing need for a reliable means for an identification and verification system cannot be overemphasis due to the increasing demand for a secure means of authentication (Kumar et al., 2018; Zhao & Kumar, 2019). One of the reliable ways of this authentication is biometric technology, and biometric technology is a useful tool for authentication, especially in high-security areas (Gupta & Anne-marie, 2018).

The word biometrics is a two combine the word of the Greek word bio and metric, which is "life meaning bio and measurement meaning metric" (Chand & Rani, 2018; Malode & Patil, 2017). Biometric technology is defined as any technique that can use measurable physiological or behavioral characteristics to discriminate one person from another (Torrico *et al*., 2018). Common physiological biometric traits include iris, fingerprints, facial, hand geometry, and retina images. Whereas, common behavioral biometric traits include: voice recording, signature, and keystroke rhythms. It is noted that behavioral biometrics, in general, include a physiological component as well (Sallehuddin *et al*., 2017).

All biometric systems work in the same manner, and the first process is enrollment in which each new user is registered into the database (Trokielewicz, 2016). Information about a specific characteristic of the individual is captured. This information is usually passed through an algorithm that turns the information into a template that the database stores (Viriri & Tapamo, 2017). Note that it is the template that is maintained in the system, but not the original biometric measurement as many people may suspect. Compared with the original measurement of the biometric trait, the template has a tiny amount of information; it is no more than a collection of

numbers with little meaning except to the biometric system that produced them (Hofbauer *et al*., 2015). When a person needs to be recognized, the system will take the appropriate measurement, translate this information into a template using the same algorithm that the original template was computed with, and then compare the new template with the database to determine if there is a match, and hence, either verification or identification (Boles & Boashash, 1998).

Generally, biometric identity verification is a difficult task, because most for the biometric traits are not physically distinct to each other. Biometric individual authorization and authentication is a known problem that requires a careful and precise procedure for verification (Chaubey, 2016; Nguyen *et al*., 2017). With the increasing importance of security, automated personal identification based on biometrics has been receiving extensive attention over the past decade (Tan *et al*., 2003). Contrary to the traditional methods, the biometrics has a proven advantage over the traditional methods and has been able to solve their issues, such that the user is authenticated by using his/her physical or behavioral traits for verifications (Bowyer *et al*., 2008; Umer *et al*., 2017).

Securing our economic transaction, airports, social activities, personal document, surveillance, and other day-to-day activities is very important with a reliable means. It is no longer convenient and efficient for the use of methods such as a password, keycards guards, for protecting our day-to-day issues. We often forget our password or lost our keycards, so the need for something that cannot be forgotten or lost became necessary. Hence the biometric recognition became an alternative for access control (Chaki et al., 2019). The biometrics authentication system is built/ developed to use a human's physical or behavioral features to identify individuals as suppose the traditional passwords or identification cards (Daugman, 1993, 2003; Nabti & Bouridane, 2008). These features can be a fingerprint, iris, face, palmprint, finger-vein, DNA, retina, signature, or voice, among others.

In general, a biometric system consists of seven components (Baqar *et al*., 2017):

- A sensor that collects and converts the data to digital.
- Pre-processing algorithms that remove artifacts from the digital output obtained from the sensor. These algorithms usually enhance, segment, normalize the digital images from the sensor.
- A feature extractor that extracts significant features.

- A template generator that generates a biometric template which provides a discriminating representation of features.
- A storage component or the database that stores templates.
- A classifier that compares the generated template with the other stored templates for recognition. This result will be used for various applications.
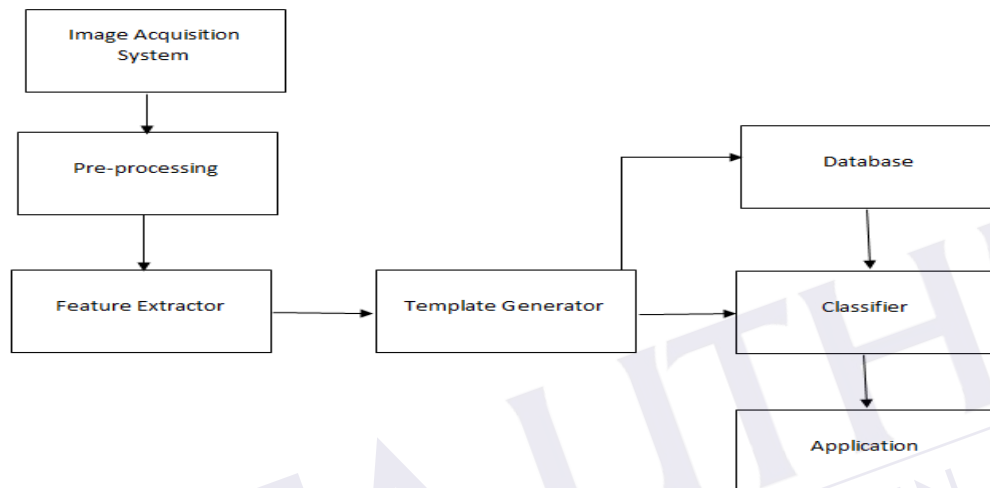
Figure 1.1: Biometric System of Authentication (Daugman, 1993).

Usually, in all biometric system processes, the processes start with image acquisition. The image acquisition system varies from the different biometric systems; iris uses iris scanner/cameras while the fingerprint system uses the fingerprint scanner. The system, as in Figure 1.1, captured the required region for the authentication. The process follows by preprocesses; this stage prepares the image for feature extraction. Next is the feature extractor, here a unique feature in the image is extracted. The distinct feature of the image is used to generate a template and save for the registration, while for verification or authentication features extracted are compared with the saved template in the database before access is granted (Daugman, 1993, 2007, 2009).

Fingerprint recognition refers to the authentication methods of identifying an individual based on the texture pattern of his/her fingerprint. Fingerprint authentication is one of the most well studied biometric systems, and it is the most used system of biometric authentication solutions (Liu *et al*., 2015). It is distinct to each individual and is not affected by aging, unlike a face recognition system. Face recognition is also a biometric system of access control; the system uses distinct features in individual

faces for authentication. Although face recognition is affected by age while fingerprint authentication requires contact of the scanning device with the individual, other biometrics are faced with challenges. The iris recognition is an internal organ; it is neither affected by age nor require individual to have contact with the authenticating devices.

Iris is a thin membrane that is located between the cornea and lens of the human eye. The average diameter of the human iris is 12 mm, and the size of pupil changes between 0.1 and 0.8 of the iris radius (Bekerman et al., 2014). The view of the human eye from the CASIA database, as shown in Figure 1.2 from its view; it has consisted of eyelashes, iris, pupil, sclera, and eyelids. The primary function of the iris in the human eye is controlling the volume of light reaching the pupil. It consists of two layers; stroma and beneath the stroma is the epithelium layer. The stromal layer comprises blood vessels, two iris muscles, and pigment cells. The epithelium layer comprises pigmented epithelial cells. The color of the iris is usually determined by the density of stromal pigmentation (Daugman, 2003; Karakaya, 2016; Smerdon, 2000). Iris formation begins during the third month of gestation, and the edifices creating the iris patterns are completed by the end of the first year of human life, whereas; stromal pigmentation takes place for the first few years. The formation of unique iris patterns is not related to any genetic factors (Shen & Khanna, 1997). Iris pigmentation, which determines the color, is the only characteristic that is dependent on genetics. The epigenetic nature of iris patterns results in independent patterns for the two eyes of an individual and uncorrelated patterns for identical twins.
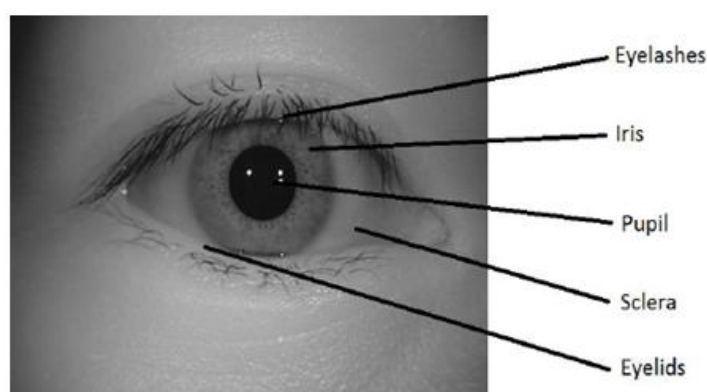
Figure 1.2: Human eye. Image from the CASIA iris database (Tan et al., 2010a).

Iris recognition is considered one of the most accurate and reliable forms of access control in recent researches (Engineering, 2013; Li, & Micheli-tzanakou, 2011; Liu, 2006; Roy *et al*., 2011; Sarmah & Kumar, 2013). Iris recognition system was first proposed by Daugman (1993), who developed a high-confidence visual recognition of the person. In his work, a state-of-the-art iris recognition algorithm was proposed to achieve remarkable performance. The iris recognition comes from the rich texture and unique pattern part of the human eye, and the permanency of the iris texture as it is not affected by age.
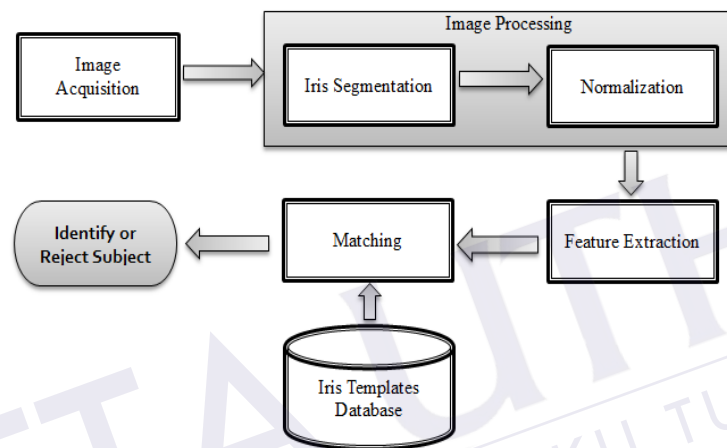
Figure 1.3: Steps in Iris Recognition System (Nguyen et al., 2017).

The steps in the iris recognition system are shown in Figure 1.3. The steps include; Image Acquisition, Image Preprocessing, Feature Extraction, and Matching. In image acquisition, iris images are captured using Near-InfraRed (NIR) illumination with a wavelength between 15 cm and 46 cm. Images acquired using such wavelengths tend to highlight the intricate texture of the iris, rather than its pigmentation and between 100 to 200 pixels (Charan, 2017). This helps to appropriately capture the texture of dark-colored irises, thereby contributing to better recognition performance. However, in preprocessing image segmentation and image normalization is performed. This prepares the iris image for feature extraction. First, the iris is segmented from remain part of the eye, as it will be almost impossible for the capturing device to capture the iris alone (Thavalengal & Corcoran, 2016). Several methods are used to carry out this task, these methods integrodifferential operator (Soliman *et al*., 2017), Hough transform (Umer *et al*., 2016), among others, while in normalization method

like rubber sheet model (Jassim & Nseaf, 2016), Wilde's registration, among others, are used to transform the segmented spherical iris image to rectangular iris image (Wildes, 1997). The process of normalization helps with solving the problem in iris dilation. This is because the area enclosed by the inner and outer boundaries of an iris can vary due to the dilation and contraction of the pupil. The effects of such variations need to be minimized before comparing different iris images. Next is the feature encoding; this is the process extracting a highly distinct and unique feature from the normalized image. Several methods are also used here include 2D-Gabor wavelet (Liu *et al*., 2017; Sun *et al*., 2015), Wavelet Transformation (Dhage *et al*., 2015; Tallapragada & Anatomy, 2010), Fast Fourier Transformation (Al-Zubi *et al*., 2015). Lastly, the image matching, methods like Hamming Distance (Saminathan *et al*., 2015; Xiaoxing *et al*., 2015) are used to compare the similarity between the captured image and the registered image in the database.

Among all the stages in the process of iris recognition, feature extraction is a crucial stage (Sankar *et al*., 2015). Moreover, the Wavelet Transform emerged as a popular technique for image coding applications (Mandal *et al*., 2007). As such, this research with a focus on feature extraction and a suitable wavelet will be considered as the method of feature extraction. One advantage of the 2D wavelet feature is that a small change in the features corresponds to a small change in perceptual quality. This is very important while carrying out recognition in noisy surroundings (Sankar *et al*., 2018).

A benchmark database is essential and can not be sacrificed for the sake of the creation of recognition. The premise behind any recognition system is the failure of a statistical independence test for the human iris' random textures, and the iris image requires so many degrees of freedom as a complex texture. Many parameters in the iris recognition system should be considered, and optimal threshold values should be assigned to these parameters to ensure maximum accuracy of recognition. These parameters include, respectively, the dimensions of the input image, the radial and angular resolution of the standardized rectangular image r and θ. That will be used to calculate the number of extracted coefficients. The most commonly used dataset includes the CASIA database, UBIRIS Database, and the MMU Database.

The CASIA iris database, developed by the Chinese Academy of Science-Institute of Automation, is the first freely available iris database. The first versions of CASIA iris databases use an ideal acquisition environment at close distance, with stop

and look, and use NIR (Near Infrared) light sources that mimic the same conditions that Daugman's iris recognition system has suggested and used. The CASIA iris database is currently in four versions. CASIA-IrisV4 is an expansion CASIA-IrisV3, which includes six subsets. The three CASIA-IrisV3 subsets are CASIA-Iris-Interval, CASIA-Iris-Lamp and CASIA-Iris-Twins respectively. The three new subsets are CASIA-Iris-Distance, CASIA-Iris-Distance, and CASIA-Iris-Thousand.

The reason behind the development of the UBIRIS database is the need for a new noisy iris image dataset that simulates the less restricted environment in the capture system that will be used as a tool to create reliable proposals for recognition. The UBIRIS database is the noisiest, introducing new noise factors caused by; motion blur and rotated iris images of moving subject, poor focus images, distortion of eyelids and eyelashes, a specular and light reflection of visible wavelength light sources, and finally closed eye iris images. These noise factors make the UBIRIS database a suitable setting for unconstrained iris recognition algorithms to be created.

1.2   Problem Statement

In recent years, a statistical market survey shows that global biometric authentication and identification are expected to grow from USD10 billion in 2015 to USD25 billion by 2020 ("GBAIM" market survey, 2015). Biometric recognition is considered the most straightforward, secure, and efficient system for access control (Chaki et al., 2019). However, many pieces of research are going on to make these more accessible for use. Evidence of these developments can be seen in the integration of fingerprints biometric authentication on our mobile phone. The Iris recognition system was first introduced by Daugman (1993). The most notable work and commercially accepted is reported by Daugman, who proposed a 2-D Gabor filter to demodulate phase information of an iris image to create an IrisCode for the authentication.

Iris recognition has been verified to be one of the most accurate and reliable biometrics authentication (Harifi & Bastanfard, 2015), unlike facial recognition and fingerprint. The facial recognition has a significant problem since the human faces change over time due to growth development in human nature. The identified problems make iris recognition an alternative as the best biometric authentication, the iris is

neither affected by age nor requires an individual to have contact with its scanning device (Omran & Al-Hillali, 2016; Sallehuddin *et al*., 2016).

Presently, iris recognition methods can work very well with frontal-looking and high-quality images (Trokielewicz & Bartuzi, 2016). Daugman's 2D Gabor wavelet method has been tested and evaluated using massive databases, such as the CASIA database, UBIRIS database, and MMU database, among others. However, most existing approaches are not designed for non-cooperative users and cannot work with off-angle or partially captured iris images (Deshmukh & Prasad, 2015).

Recognition can be pretty good if canonical poses and simple backgrounds are employed, but changes in illumination and angle create challenges (Ahmadi et al., 2019; Pato & Millett, 2010). Recognizing an individual with incomplete or partially captured images in biometric technology continues to be an essential challenge today. Partially captured images or images with noise or occlusion is a well-known research problem, and many researchers have tried to address the problems in a different capacity.

During the last two decades, various algorithms have been proposed to address the issues from the level of segmentation to normalization and down to the feature extraction. Other researchers also focus on solving these issues during matching. Secondly, the iris features are often deformed, and it is very challenging to perform feature extraction and matching.

One of the most crucial stages in iris recognition is iris feature extraction. For a partially captured image to be successfully recognized, this stage must be well studied, and a suitable solution is proposed. One of the most commonly used algorithms for feature extraction is the Gabor wavelet filter (Huo *et al.*, 2019), which often shows a good result for feature extraction. However, the Legendre Wavelet is based on a polynomial and can be built on a different degree of the Legendre polynomials (Chang & Isah, 2016; Kumar *et al.*, 2018). Moreover, the Legendre wavelet shares all the properties of the Gabor wavelet, and this gives the Legendre wavelet an added advantage over the Gabor Wavelet. However, the Legendre Wavelet this being the first time it will be used as a filter for feature extraction. There is a need for the development of the Legendre wavelet filter. Images often have properties that differ continuously in some areas and discontinuously in others. Thus, in order to accurately estimate these spatially varying properties, it is essential to use approximating functions that can accurately model both continuous and discontinuous

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