WAVELET AND MOMENT INVARIANTS BASED FEATURES SELECTION USING VORONOI DIAGRAM FOR FACE RECOGNITION

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To my mother, father and beloved family

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ABSTRACT

Face recognition is a biometric authentication system for human security and personal identification that has become a field of interest in pattern recognition and computer vision societies in recent years as it has become increasingly important and commonly used for legal and personal identification in various fields such as visa information system, access control and multimedia search engines. However, distinct illumination, pose and blurring of facial images have become a big challenge in finding important facial features and facial representation in these fields. Therefore, this thesis proposes a facial recognition framework based on multi-feature selection approach. The framework in this thesis consists of eight stages: face pre-processing, segmentation, detection, cropping, transformation, extraction, classification and verification. The experiments were performed on gray scale frontal facial image with 750 images applied from three different standard facial databases namely BioID, ORL and Yale. In face segmentation, detection and cropping stages, Voronoi Diagram and Delaunay Triangulation methods have been applied. Wavelet transform and moment invariants methods have been used to extract facial image features. All features were fed into Radial Basis Function neural network for classification and verification purposes. The results show that a recognition accuracy rate of more than 92% has been achieved as compared to other proposed methods. Therefore, the framework in this thesis would be beneficial for the field of face authentication or verification due to its robustness and invariance to pose, illumination, and expression.

ABSTRAK

Pengecaman wajah adalah sistem pengesahan biometrik untuk keselamatan dan pengenalan manusia yang telah menjadi bidang tumpuan dalam pengecaman corak, dan masyarakat visi komputer pada tahun-tahun kebelakangan ini. Sejak itu, ia menjadi sangat penting dan lazim digunakan untuk kes perundangan dan pengenalan peribadi dalam pelbagai bidang seperti sistem maklumat visa, kawalan akses dan enjin carian multimedia. Walaubagaimanapun, perbezaan dalam iluminasi, gaya, dan kekaburan imej wajah menjadi cabaran besar dalam mencari fetur penting wajah dan perwakilan wajah dalam bidang-bidang ini. Oleh itu, tesis ini mencadangkan rangka kerja pengecaman wajah berasaskan pendekatan pemilihan pelbagai ciri. Rangka kerja dalam tesis ini terdiri daripada lapan peringkat, iaitu; pra-pemprosesan wajah, segmentasi, pengesanan, keratan, transformasi, pengekstrakan, klasifikasi dan pengesahan. Eksperimen telah dijalankan pada imej wajah depan pada skala kelabu yang menggunakan 750 imej daripada tiga pangkalan data wajah yang berbeza iaitu BioID, ORL dan Yale. Dalam peringkat segmentasi, pengesanan dan keratan wajah, kaedah gambarajah Voronoi dan segitiga Delaunay telah digunakan. Kaedah transformasi Wavelet dan invarian momen telah digunakan untuk mengekstrak fetur-fetur pada imej wajah. Semua fetur ini dimasukkan ke dalam rangkaian neural Fungsi Asas Radial untuk tujuan pengklasifikasi dan pengesahan. Keputusan menunjukkan bahawa kadar ketepatan pengecaman lebih daripada 92% telah dicapai berbanding kaedah-kaedah lain yang dicadangkan. Oleh itu, rangka kerja dalam tesis ini akan bermanfaat bagi bidang pengesahan atau kesahihan wajah kerana keteguhan dan ketidakvariannya terhadap gaya, iluminasi dan ekspresi.

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LIST OF SYMBOLS

I	-	Image intensity
θ	-	Sub-band of facial feature
dc	-	Distance
cH	-	Detailed coefficients matrices of horizontal
$cV,$	-	Detailed coefficients matrices of vertical
cD	-	Detailed coefficients matrices of diagonal
ψ	-	Structuring element
Θ	-	Erosion
$\oplus$	-	Dilation

LIST OF ABBREVIATIONS

ANN	-	Artificial neural network
CH(S)	-	Convex hulls
DT	-	Delaunay triangulation
DWT	-	Discrete wavelet transform
FFT	-	Fast four transformations
MFNN	-	Multi-feature neural network
MLP	-	Multi-layer perception
RBF	-	Radial basis function
SFNN	-	Single-feature neural network
STFT	-	Short-time fourier transform
VD	-	Voronoi diagram
V(g)	-	Voronoi region
VS	-	Voronoi vertex

CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, the computer vision field becomes necessary for people. Many applications in this area have improvements to use in any situation, such as: house surveillance, human computer interface, video summarization, visual simulation, home entertainment, games, and robot. There are many technologies in the computer graphic field, such as pattern recognition, machine learning, optical physics, and digital image processing. Its development can be useful in commercial applications: for example, home robotics, access control, video conferencing, house surveillance, identify the criminal, investigation immigration and so on. Computer vision researches are divided into four levels. Firstly, the image formation levels consist of physics, optics and cameras. Secondly, the low-level visions consist of derivatives and optical flow. The thirdly is mid-level visions such as object segmentation, tracking, and so on. Lastly, the high-level vision comprises of understanding underlying semantics. The image formation and low-level vision are performed by theoretical knowledge. In contrast, middle level and high-level vision are short of theoretical descriptions and solution. They need much knowledge to learn and to support for research in the next several years (Brooks, 2008).

A basis of the pattern recognition system is a biometric system based on acquiring data from an individual image. The biometric refer to individual characteristic features that describe the part of our own individual physiology, natural posses and identifies unique features of a particular person. It can be separated into two categories. Firstly, behavior characteristic consists of gait, keystroke, voice and signature. Secondly, physical characteristics consist of eye, hand, vein and face. In literature reviews, fingerprint technique and iris technique performance made better than face recognition technique for personal identification (Jain *et al*., 2004; Wayne, 2010).

Over the last decade, face recognition approaches can be categorized into two general groups, holistic and feature-based approach. Holistic approaches, the face images have performed in 2-dimensional holistic patterns, which determined much more frequently than feature-based approaches. In feature-based approaches, the relationships of shapes and geometrical are used to analyze the individual facial features, which consist of eyes, mouth and nose. However, feature-based approaches are more robust against than holistic approaches in rotation, scale and illumination variations. In contrast, the successes of these approaches depend on the technique of facial features detection (Dabbaghchian *et al.,* 2009).

Moreover, face recognition became to a popular and interest field of biometrics, pattern recognition, and computer vision societies for human security and identification. It is still one of most significant and common physiological characteristics of human beings that are due to a passive task without participant's cooperation by placing their hands or eyes on the equipment. The aim of face recognition is to identify or verify one or more persons from still images or video images of a scene using a stored database of faces. Many techniques have been focused on how to improve the accuracy of face recognition that is motivated by increased the number of real-world applications. However, before the face recognition can function on the image, the system should determine the acquisition of an image such as camera image or video image that refers to an automated or semi-automated process of matching facial image. The pipeline of face recognition

has emerged that consist of four stages: detection, alignment, representation and classification (Tan *et al.,* 2006; Lu *et al.,* 2007; Vu *et al.,* 2012).

A very important and difficult task in face recognition is the condition of illumination, distortion and cameras that are significantly larger than the image variations. Because it effects the change in face identity or achieves good recognition results. Face recognition in various lighting conditions is a still difficult problem when the acquisition face images are taken from high dynamic range scenes. It is due to in any location of the surveillance system that cannot control the illumination and effect to the recognition rate (Kao *et al.,* 2010). Thus, the face image variation is still the core challenge of uncontrolled face recognition results. There are difficult for machine to discriminate and cast in the numerable image on any given 2-D face image that depends on its position, distance, orientation, lighting and background. Especially, both variations of illumination and pose are influenced to feature descriptor in case of difference of face image and the same person. At the same time, the uncontrolled face recognition looks like research problems that are paradigmatic and everlasting for pattern recognition (Deng *et al.,* 2010; Vu *et al.,* 2010).

1.2 Background of Problem

Although face recognition can recognize an uncooperative face in uncontrolled environments and arbitrary situation, many techniques are limited to conditions of controlled environment that are impractical in the real-world application. In contrast, there are still unsolved some problems for a person's face to appear such as, Illumination variation, pose change and facial expression variation that is the basic existing challenges in this area (Dabbaghchian *et al.,* 2010). There are many problems in the processing of face recognition. Some problem comes from the variation of images in the same face that due to changes in parameter, for

example, background, illumination, expression, beards, hair and mustache (Lu *et al*., 2007). Several techniques in the 2-D image can be worked well in face recognition that can be performed under illumination variation, when the illumination and pose are changed to occur, the accuracy rate is decreased. Thus, the factor of pose variation has become a challenge to work on this area. In addition, the problem of facial expression is also significant that affects the high-frequency components for experimental. Another problem is the occlusion such as eye glasses, beard, arm, cap, and mustache (Abate *et al*., 2007).

In fact, not universally applicable segmentation technique can work perfectly for all images. Thus, the suitability depends on a characteristic of acquired images that are both varying intensity and many other conditions. Many researchers explore and implement a method for enhancing the recognition rate in face recognition. Some problems of the face detection problem have already been solved, but it still has incomplete accuracy rate. There are two methods to deal with illumination variations on face recognition: image enhancement and face relighting. The usefulness of the image enhancement method is generally found one of the criteria at the expanse of the face image. The face relighting method is performed a face image under any lighting condition. It is simply to adopt an image enhancement tool to conserve the visual contrast impression of the original image (Kao *et al.,* 2010).

In the combining techniques for face recognition, global and local structures are employed to suffer from the small sample size problem in high dimensional data. This method is properly to address the singularity problem and applied to improve the classification performance of locality preserving projections on face recognition. However, the big problem with their method is very expensive computation cost. Due to both of singular value and Eigenvalue decomposition are performed in null space (Yu *et al.,* 2006; Zhu and Zhu, 2007; Yang *et al.,* 2008).

The feature extraction is an important part of the feature extraction process and strongly influences the recognition accuracy, but it has remained not enough

attention. For example, Jing and Zhang (2004) presented the approach to find discriminant bands in the transformed space. Their approach finds the discriminant coefficients in the transformed space. The result showed possible to lose a discriminant coefficient placing beside the non-discriminant coefficients in a group Dabbaghchian *et al.* (2008). Furthermore, the conventional approaches are not necessarily efficient in all the applications and for all the databases. Dabbaghchian *et al.* (2010) proposed the approach to extract proper features for face recognition based on a novel approach to Discrimination power analysis (DPA) and Discrete cosine transform (DCT) coefficients to select features with respect to their discrimination power. The experiment presented their approach can be implemented for any feature selection problem as well as DCT coefficients and able to find the best discriminant coefficients for each database.

Although, the classical holistic subspace-based is a well-known method for speed and modesty in face recognition, which can be used for natural extension to linear illumination model. Because, the performance of recognition depends on a brittle of alignment variation and minor occlusions such as saying, a wisp of hair, a blinked eye, or an open mouth (Wagner *et al.,* 2012). A sparse representation-based classification (SRC) method has been proposed for solving the recognition problem about finding a sparse representation of the test image in the training set, which desired from some sparse error in occlusion. Their method has demonstrated impressive recognition performance by solving a simple convex program. However, it cannot perform with misalignment between the training and test images, and it needs strong illumination sets of the gallery images (Wright *et al.,* 2009).

Neural networks have been used in conventional classifiers that are the more efficient result comparison with some conventional methods. These methods are the attractive tools for many pattern classification problems (Lee and Landgrebe, 1997). Lippman (1981) presented the popular method of these classifiers based on multilayer perceptrons (MLPs) that are used to train the approximate complex discriminant function. However, it requires many of parameters to determine and many of iterations training networks. The central of this network is a multilayer

topology, which effect to the problem of learning algorithm. The important factors of learning problem come from network topology, weight initialization and input signal. Recently, radial basis function neural networks (RBFNN) have been widely used and very interesting for engineering problems. In addition, it can perform the global optimal approximation and classification capability with the fast convergence of the learning procedures (Park *et al.* 2008; Balasubramanian *et al.* 2009). However, RBFNN is not free limitation. Due to the discriminant function of RBFNN has the relatively basic geometry that is involved the limited geometric variability in the elemental receptive fields of radial basis that is located in the hidden layer of the RBF network (Oh *et al.,* 2012).

This thesis will also propose a framework to improve the performance of face recognition to the complexity problem of image acquisition based on the selected facial features and adjusting the weighting. The key point of this thesis is face detection using Voronoi diagram and feature's selection using wavelet transformation. The moment invariants are used to extract face features and verify by using RBFNN. The combinations of these methods are applied to enhance the recognition rate of the face recognition.

1.3 Research Question

One important technique of the approaches applied in combination Voronoi diagram for face detection, wavelet transformation and moment invariants for feature extraction, and verification based on RBFNN. This thesis concerns about accuracy of recognition to answer the following research question:

1) What are the important facial features that can be used to enhance the face recognition accuracy rate?

2) How can moment invariants feature extraction with sub-band wavelet transformation identify human face recognition?

3) How to extend the Voronoi diagram detection method used as a face recognition?

4) Can combination of the Voronoi diagram, wavelet transformation, moment invariants, and RBFNN to produce a better recognition accuracy rate?

1.4 Objectives of Study

The main objectives of this thesis are summarized as follows:

1. To identify important features that can be used to extract the most important face image using wavelet transformation and moment invariants algorithm to improve the recognition accuracy rate of face recognition system.

2. To investigate the effectiveness of using moment invariants feature extraction with sub-band wavelet transformation for identifies human face recognition.

3. To design Voronoi diagram detection extension to be used in face recognition.

4. To investigate a combination method between Voronoi diagram, wavelet transformation, moment invariants, and RBFNN to produce a good face recognition.

1.5 Scope of Study

In order to accomplish the objectives of this thesis, focus on how to produce a good recognition rate using the proposed method. The following aspects are the scope of research for those objectives.

1. This study focuses only on face detection and cropping the facial image that consisted of eyes, nose, and month through the extraction of important facial features using Voronoi diagram, wavelet transformation, and moment invariants

2. The study uses 1575 grayscale face images from the three standard databases (BioID, ORL and Yale). There are limited on front view of still face image that assumed to be unknown illumination, position, orientation, gender, expression, eye glasses and scaling in an arbitrary image.

3. Comparison and evaluation of methods done with benchmarks of same face database but different parameter setting/methods and focus on only the recognition rate.

1.6 Significance of Study

The study investigates face recognition tasks using the combined method of the Voronoi diagram, wavelet transformation, moment invariants and RBFNN, which can help to solve the problem of face recognition. The significance of this thesis is to propose methods for face recognition enhancement using the combination methods. This thesis extracts the important features in facial image using a combination of wavelet transformation, which is used to create the facial sub-bands

and selecting the importance level of features, moment invariants which is used to extract the central features of the facial sub-band. RBFNN method has performed based on supervised learning method that can obtain the good verification result. This proposed method considers the advantage of those methods to extract the important facial features in the source face image, which is a small facial and optimal feature. The performance of the proposed methods is evaluated based on the standard face database and compared with several methods that using same database and different technique.

1.7 Research Contribution

The expected contributions can be described as following:

1. Feature selection of proposed method can be used to extract the most 2D grayscale face image using a combination of wavelet transformation and moment invariants method.

2. More effective face recognition based on a combined method of the Voronoi diagram, wavelet transformation, moment invariants and RBFNN.

3. Voronoi diagram can be used to detect face image and extended to implement on the face recognition.

4. Better recognition accuracy rate using the combination of the Voronoi diagram, wavelet transformation, moment invariants, and RBFNN.

1.8 Thesis Organization

This thesis is organized into eight chapters as follows:

Chapter 1, *Introduction*: this chapter presents a general discussion on issues that need to be addressed in this research area by stating the problems, the objectives, the scope and expected contribution of this thesis.

Chapter 2, *Literature Review*: this chapter presents the literature survey about various in the face recognition. It discusses the related of face recognition with several techniques, which will become the supporting elements in the development of this thesis.

Chapter 3, *Research Methodology*: this chapter describes the methodology framework used to achieve the objectives of this thesis. Also, the main experiments of this thesis: the input face image, face pre-processing, face segmentation, detection and cropping, face transformation and extraction, face classification and verification, analysis, implement and summary are briefly presented.

Chapter 4, *The Face Segmentation, Detection and Cropping Framework,:* this chapter presents the details of a framework, the fundamental of Voronoi diagram and Delaunay triangulation for face segmentation, detection and cropping.

Chapter 5, *Face Transformation and Extraction*: this chapter introduces the detail of face transformation for achieve the importance of face sub-band images based on wavelet transform and feature extraction based on moment invariants.

Chapter 6, *Face Classification and Verification*: this chapter describes the mathematical of RBFNN and the details of neural network design, training, testing and classification.

Chapter 7, *Result Analysis:* this chapter presents important results of face recognition based on the proposed framework compare with the previous methods as the same database and discussion.

Chapter 8, *Conclusion and Future work*: this chapter discusses and highlights the contributions and findings of the research work and recommendations for future study.

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