FACE RECOGNITION SYSTEM USING PRINCIPAL COMPONENT ANALYSIS AND FUZZY ARTMAP

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To my beloved

Husband, son, and parents

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ABSTRACT

Research on face recognition system has been conducted over the past thirty years. The common problem of face recognition systems is catastrophic forgetting where they need to retrain the whole data in order to add a new data. As a result, the training period, processing time, hidden layers and matrix size of input network are increased. This research focused on solving the catastrophic forgetting problem and improving recognition rate. In this thesis, a face recognition system based on Fuzzy Artmap (FAM) as a classifier has been proposed. FAM is an incremental learning approach which offers a unique solution for stability-plasticity dilemma by preserving previously learned knowledge and adapting new patterns. Experiments were conducted to evaluate the performance of both FAM and Multilayer Perceptron Neural Network (MLPNN). The recognition rate obtained were 97.2% and 98.5% using FAM, 90.56% and 81.5% using MLPNN based on local and Olivetti Research Lab (ORL) datasets, respectively. Using FAM, the recognition rate improved by 6.64% and 17% for both datasets, respectively. The results proved that the proposed system offers a solution for catastrophic forgetting and improved recognition rate.

ABSTRAK

Sistem pengecaman muka secara automatik telah dibangunkan semenjak 30 tahun yang lalu. Masalah yang biasa dihadapi oleh sistem pengecaman muka dikenali sebagai *catastrophic forgetting* yang mana kesemua data baru dan lama perlu dipelajari semula sekiranya terdapat penambahan data baru. Ini menyebabkan tempoh latihan, tempoh memproses data, jumlah lapisan tersembunyi dan saiz umpukan matrik rangkaian meningkat. Penyelidikan ini tertumpu kepada mengatasi masalah *catastrophic forgetting* dan meningkatkan peratusan pengecaman. Dalam thesis ini, sistem pengecaman muka berdasarkan *Fuzzy Artmap* (FAM) sebagai teknik pengasingan telah dicadangkan. FAM mempunyai ciri-ciri *incremental learning* yang mana ia memberikan penyelesaian yang unik yang dikenali sebagai *stability-plasticity dilemma* dengan cara mengekalkan pengetahuan yang sedia ada dan mampu menerima data baru tanpa menjejaskan pengetahuan yang telah dipelajari. Eksperimen yang dijalankan menilai FAM dan *Multilayer Perceptron Neural Network* (MLPNN). Peratusan pengecaman yang betul adalah 97.2% dan 98.5% menggunakan FAM, 90.56% dan 81.5% menggunakan MLPNN berdasarkan data local dan *Olivetti Research Lab*. Menggunakan FAM, peratusan pengecaman meningkat sebanyak 6.64% dan 17% untuk kedua-dua jenis data. Keputusan eksperimen membuktikan bahawa sistem dibangunkan dapat mengatasi masalah *catastrophic forgetting* dan meningkatkan peratusan pengecaman.

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LIST OF ABBREVIATIONS

PIN	-	Personal Identification Number
ATM	-	Automatic Teller Machine
PC	-	Personal Computer
TV	-	Television
CCTV	-	Closed-Circuit Television
ID	-	Identification Number
FRS	-	Face Recognition System
JPEG	-	Joint Photographic Experts Group
BMP	-	Bitmap
PGM	-	Portable Gray Map
PCA	-	Principal Component Analysis
FERET	-	Facial Recognition Technology face database
ORL	-	Olivetti Research Laboratory
LDA	-	Linear Discriminant Analysis
LBP	-	Local Binary Pattern
EBGM	-	Elastic Bunch Graph Matching
MLPNN	-	Multilayer Perceptron Neural Network
FAM	-	Fuzzy Artmap
GA	-	Genetic Algorithm
SVM	-	Support Vector Machines
ART	-	Adaptive Resonance Theory
RBF	-	Radial Basis Function

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CHAPTER 1

INTRODUCTION

1.0 Biometric Application

Although research on biometric technology has been around for several years, the interest in this area has been tremendously renewed due to the event on 11th September, 2001. There are increasing demands on security and biometrics applications in this area are becoming more popular. In fact, many countries have employed biometric technology for airport security, border control, immigration, database in law enforcement, surveillance in public and private premises and controlling access to secure areas (Frost & Sullivan, 2003).

Biometric are measurement of physiological or/and behavioral characteristic that can be used to verify and identify individual identity. Physical biometric refers to human body characteristic such as face, iris, fingerprints, hand and gesture geometry, whereas behavioral biometric include voice, gait, handwritten and signature. Individual physical or behavior are unique and differ from each others (Jain, A.K., 2004).

Much of the research work on biometrics has focused on identification application. According to Jain, A.K. (2004), the traditional identification approaches are based on something we have for example smart card and token or something we know such as password and personal identification numbers (PINs). However, these

two approaches are low-reliability techniques and vulnerable because they can be lost, stolen, forgotten or guessed.

Therefore, biometric offers a solution for something we have which is most secure and convenient identification tool, no more password, PINs number or ID cards because biometrics are based on our physical or behavior characteristic. It can't be borrowed, stolen, forgotten, copy or compromise and impossible for someone to forge other people biometric characteristic.

Many biometric system applications are either one-to-one verification or one-to-many identification. Both applications lead to separate goals. The differences of both applications as explained by Jain, A.K. (2004) is elaborated here.

In one-to-one verification task, the system tries to verify the identity of the user based on information provided. The system compares a user current face image against a template face image whose identity is being claimed by the user. For example, when a person presents his biometric features and he claimed his identity using Staff ID as Ahmad to the system, the system then fetches the template of Ahmad. If the presented biometric features match Ahmad's template, the system verify that the user is Ahmad and is an authorized user. Otherwise, the system rejects him. These applications include those that authenticate identity during point-of-sale transaction or that control access to computer or secure building.

In one-to-many identification, the system seeks to determine the person without any information or participation of the person. The system compares a query of face image against all the template images in the database to determine the identity of the query faces. For example, once the devices capture the biometric of the person, the system will then compare against a database of biometric template and looks for a match in its database. Systems that rely on identification include those that the police use to identify people from fingerprint.

Currently, there are various biometric technologies in the market to support various applications in real world. Those applications used common biometric such as fingerprints, face, iris and hand geometry.

A fingerprint looks at the unique characteristics patterns found in the human fingertip. Fingerprints have been used in criminal identification by police department world wide. For example, the Federal Bureau of Investigation's (FBI's) Integrated Automated Fingerprint Identification System (IAFIS) provided automated fingerprint search capabilities where the system compares the submitted fingerprint information against a database of several million fingerprints, and thus has a potential criminal history. In commercial application, as given by Phillips, P.J. *et al.* (2000), a fingerprint has been used during the 1996 Olympic Games as controlled access and also used by Disney World as season-pass holders' verification at the entrance of the theme park. Beside that, according to Uludag, U. *et al.* (2004), fingerprint also has replaced password based security. Most systems use single fingerprint that the account holder actively provides to the system. To log on into a system, the user needs to type their username and place their finger on a scanner. Once the system identifies their identity, users are allowed to use the particular application.

An iris-based biometric, involves analyzing features found in the colored ring of tissue that surrounds the pupil (Liu, S. *et al.*, 2001). According to National science and Technology Council (2006), the Privium system at Schiphol Airport in Amsterdam, Project IRIS at London's Heathrow Airport and Expellee Tracking System by United Arab Emirates (UAE) are some examples of iris recognition implementation in immigration system. IRIS, which uses a two-eye iris-recognition system, stores data about enrolled travelers in a database for identification. Privium uses a one-eye system, and stores a traveler's biometric details on a card for verification. The UAE requires that all visitors have their iris scanned on arrival, and these scans are checked against a database of people barred from entering.

Hand geometry involves analyzing and measuring the shape of the hand. An example of this technology application is US Passenger Accelerated Service System (USPASS). This system uses hand geometry to identify and process preens rolled,

low-risk frequent travelers through an automated immigration system (Phillips, P.J. *et al.*, 2000).

Face recognition analyzes facial characteristics. It requires a digital camera to develop a facial image of the user for authentication. SmartGate, a face recognition system, has been tested by Customs at Sydney International Airport since November 2002 (Australian Custom Service information on *Smartgate Information Sheet*, 2004). The primary objective of the trial was to develop and introduce a system of self-processing utilizing face recognition biometric technology to confirm identity and streamline the existing crew facilitation process while maintaining the integrity of the border.

Amongst common biometric technologies discussed earlier, the face recognition has a high potential to be used widely due to its advantages compared to other biometric technologies. Face recognition is natural, non-intrusive and easy to used. Face recognition has an ability to enroll static images, ability to leverage existing surveillance hardware such as CCTV and it is the only biometric that is passive to use, this means it does not require direct user contact or cooperation. Therefore, due to face recognition high level of universality, acceptability and collectability, face recognition is most preferable biometric tools among users.

1.1 The Face Recognition System Potential

Face recognition uses selected features in face image to identify individual identity. The system requires a camera to capture the face image and comparing it with the image stored in the database. Since 1960s, automated face recognition system have been developed. Multiple approaches have been studied to cater automated face recognition problems to improve face recognition accuracy. Amongst them are Eigenfaces, Neural Network, Support Vector Machine, Fuzzy Logic, etc. In 1990s, automatic face recognition technology moved from laboratory to the commercial world largely because of the rapid development of the technology

(Phillips, P.J. *et al.*, 2000). The face recognition has given a new life through the additional and new application especially after the September 11, 2001 terrorist attack. Those applications cover various market area such as government sector, financial sector, healthcare sector, travel and transportation sector and others verticals market area.

Based on report by Frost & Sullivan (2003), the face recognition market was worth $21.5 million, forecast to growth to $791.8 million by 2009. Table 1.1 shows the total revenue forecasts for the face recognition industry. The based year for all calculation is 2002. From the table, the world face recognition market is expected to experience the steep compound annual growth rate of 67.4%. With technology advancements, growing acceptability, emergence of new application and current high security environment, shows that the face recognition industry has a bright opportunity to move into high growth stage.

Table 1.1: Total Face Recognition Market: Revenue Forecast (World) 2000-2009

Year	Revenues ($ Million)	Revenues Growth Rate (%)
2000	6.6	…….
2001	11.8	79.1
2002	21.5	82.1
2003	47.8	122.4
2004	122.7	156.7
2005	269.7	119.8
2006	474.0	75.8
2007	625.6	32.0
2008	728.8	16.5
2009	791.8	8.6
Compound Annual Growth Rate (2002-2009) : 67.4%		

Note: All figures are rounded; the based year is 2002. Source: Frost & Sullivan

According to Frost & Sullivan (2003), the face recognition technology's revenue growth is expected to be driven by the following factors:

a) enhanced performance of technology
b) new legislation and government support

c) need for higher security solutions
d) emergences of new application areas
e) the use of existing infrastructure
f) less intrusive technology

a) Enhanced Performance of Technology: Improvement in face recognition performance played an important role in boosting the future potential of face recognition technology. Thus, improve the perception and acceptance levels among consumers and people are willing to experiment with face recognition products.

b) New Legislation and Government Support: The International Civil Aviation Organization (ICAO) has earmarked face recognition as the best suited biometric technology to be used in all machine-readable travels documents because passport already contained photograph of the individuals. The U.S Enhanced Border Security and Visa Entry Reform Act mandates the use of biometric in travel documents, passport and visas and states that all ports of entry to the US should install biometric equipment and software by October, 2004. It will also require countries participating in the Visa Waiver Program to have the same security measure. As a result of this new regulation, most country is planning to implement biometrics in their passport and face recognition is expected be an integral part of these programs.

c) Need for Higher Security Solutions: The need of higher security by various government and non government agencies has become apparent after September 11, 2001. This incident has increased awareness and understanding about the need for implementing more secure solution. This factor has been one of the major drivers for the face recognition industry.

d) Emergences of New Application Areas: The implementation of face recognition has been greatly increased due to emergence of new, high potential application areas. Video surveillance is one of the markets where the face recognition software can be mapped with CCTV cameras and be used effectively to identify people having a criminal background. Another application is the prevention of multiples identities by using face recognition technology in driver’s license, passport and visa database.

e) The Use of Existing Infrastructure: Face recognition is focusing on software development as part of the solution its offers. Thus, one major advantage of face recognition software is ability to utilized existing infrastructure such as CCTV systems. This use of existing infrastructure helps in cost control of the complete solution.

f) Less Intrusive Technology: Face recognition can capture the face image from a distance. Users do not need to come close physically with any of the sensors.

As a conclusion, face recognition technology has made useful advancement in security solution areas of applications. Due to high demand and awareness of importance of high security level, pro-biometric in legislation implementation especially legislation passed in the US, there are clear path for large scale implementation of face recognition solution, given a face recognition technology a good future and able to sustained for a long period. In addition, the usage of face recognition technology in new application such as database mining and surveillance also play a major role in face recognition potential. However, the research in enhancement of this technology must be continued so that it is able to meet the user's requirements.

1.2 Problem Statement

Many researches have been done on the development of the robust face recognition system in the last decade. However, the existing face recognition systems still face a lot of problems. Some of the problems are computation of training time, limited memory execution and ability to handle larger dataset.

According to Lippmann, R.P. (1989), a good classification performance requires selection of effective features and also a selection of a classifier that can make good use of those features with limited training data, memory and computing time. Therefore, the crucial part of designing a face recognition system is to

determine the most suitable classifier. Available classifiers are Multilayer Perceptron Neural Network (MLPNN), Support Vector Machine (SVM), Hidden Markov Model (HMM), K-nearest Neighbor, etc. However, these classifiers have their own limitation. For example, HMM is expensive in terms of memory and computing time, and K-nearest Neighbor required a lot of memory to perform its process. Figure 1.1 shows the comparison of classifiers performance in term of training time and memory requirements as mentions by Lippmann, R.P. (1989).

MLPNN is the most popular classifiers in pattern recognition. However, by using MLPNN, training time is typically longer when complex decision regions are required, or when network have more hidden layers or when the matrix size of neural network input is too large (Lippmann, R.P., 1989). The system needs to retrain the network if there is a new input data. Sometimes it reflects significant changes in the classification domain which requires new association to be learned. The new data must be completely retrained, losing previously learned associations even though some maybe useful. When retraining with additional new data, there is no guarantee that the previous network's topology, learning parameter etc will still provide a good solution (Downs, J. *et al.*, 1996).

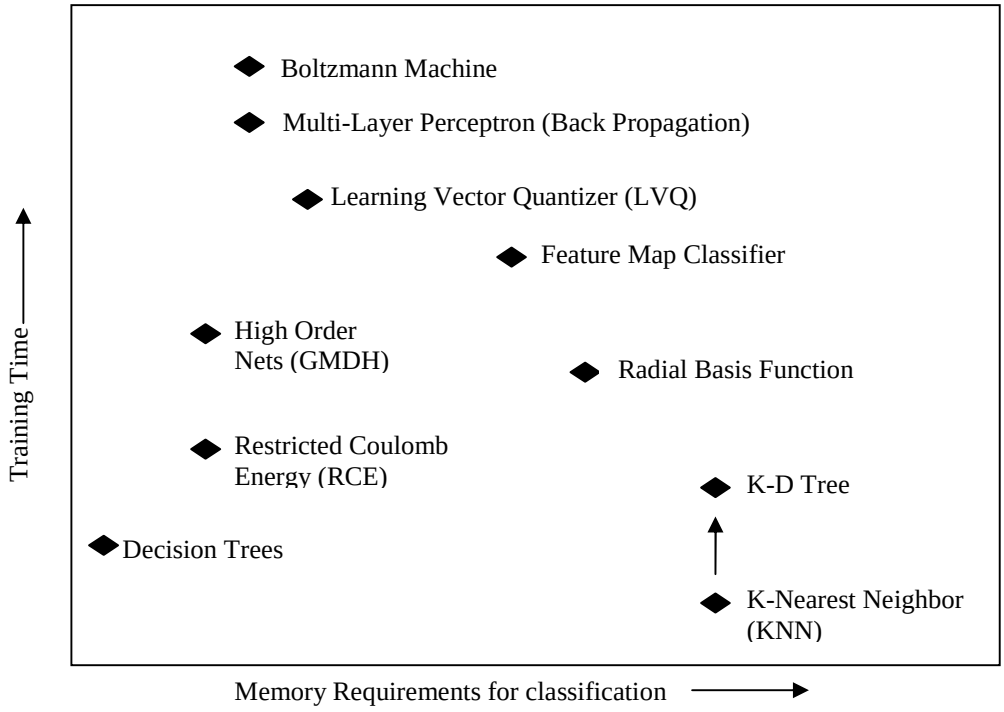

Figure 1.1 Relative differences between classifier training time and memory requirement

To overcome the issues of retraining a new data, Fuzzy Artmap (FAM) is proposed as classifiers. FAM has unique characteristics: ability to solve stability-plasticity dilemma problems by safely adapting to novel information without corrupting or forgetting previously learned information (Carpenter, G. *et al.*, 1992). The Fuzzy Artmap model can even incrementally learn novel patterns without retraining the network. This characteristic is able to shorten the training duration. Thus, Fuzzy Artmap is suitable for online training and able to handle a large database.

1.3 Thesis Objective

The objectives of the thesis are:

1. To develop a face recognition system using PCA as feature extractor and FAM as classifier.
2. To compare the performance of the proposed FAM with Multilayer Perceptron Neural Network and Euclidean Distance.
3. To investigate the effectiveness of FAM as classifier using Local and ORL dataset.

1.4 Scope of the Research and Development Phases

Scopes of the study for this project are as outline below:

1. Data collection for still images in controlled environment.
2. Enhancement of face images using Homomorphic filtering, normalization and resizing.
3. Face representation using PCA techniques.
4. Designing a FAM module to solve the problems of retraining new data.
5. Face data analysis with respect to determining the FAM parameters.

6. Comparison of using FAM with others algorithms in terms of training duration and recognition rate.

The development of the thesis is divided into three phases. Phase 1 consists of data acquisition, development of image enhancement and features extraction module. Phase 2 consists of development of Fuzzy Artmap, result and analysis. Phase 3 is comparison, analysis and conclusion. The development process is shown in Figure 1.2.

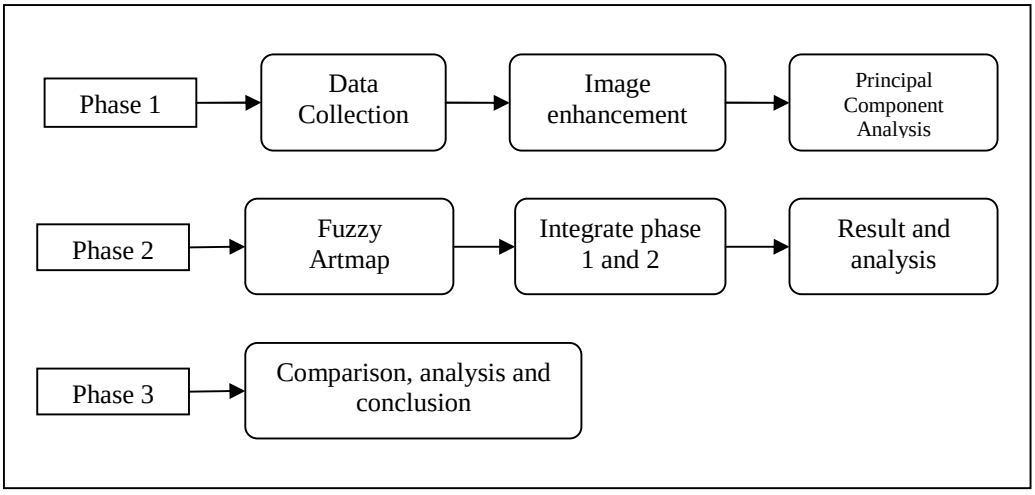

Figure 1.2 Development Phases

1.5 Thesis Outline

The thesis focuses on improving face recognition by using Fuzzy Artmap algorithm. Basically, chapter 1 describes the objective and scope of the thesis. The chapter given an overview and introduction of the work described in the thesis. It also explained the importance and potential of face recognition system and also the process involved in the development of a face recognition system.

Chapter 2 is the literature review of the thesis. This chapter describes the tasks of face recognition systems which include data acquisition, face detection, preprocessing, features extraction, features matching and face recognition. Besides

that, this chapter also describes the research that has been done on face recognition system, the problems involved and how these problems have been solved using various techniques.

Chapter 3 describes methodology used in development including system design, face representation and concept of Fuzzy Artmap algorithm.

Chapter 4 describes experimental design and results. This chapter explained experiments conducted. This chapter also explained the findings during the experiments and the comparisons test using various dataset and classification techniques.

Chapter 5 concluded the thesis, summarizing the contribution to the field of face recognition, and discussing directions and issues for future work.

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