COMPARISON OF FACE RECOGNITION TECHNIQUES: THE EFFECTS OF FEATURES AND PARAMETERS SETTING

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THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF ENGINEERING (COMPUTER ENGINEERING)

SCHOOL OF ENGINEERING AND INFORMATION TECHNOLOGY
UNIVERSITI MALAYSIA SABAH
2013

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: COMPARISON OF FACE RECOGNITION TECHNIQUES: THE EFFECTS OF FEATURES AND PARAMETERS SETTING

IJAZAH: MASTER OF ENGINEERING (COMPUTER ENGINEERING)

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DECLARATION

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ACKNOWLEDGEMENT

I wish to express my deepest gratitude and appreciation to my supervisor, Dr. Jamal Ahmad Dargham, for his continuous guidance to supervise me throughout the past few years, His advice, encouragement, motivation and valuable suggestions have provided me the necessary impetus to complete this research.

I express my truthful gratitude to my co-supervisor, Assoc. Prof. Dr. Ali Chekima for his advice, support and timely suggestions for the completion of this work. I sincerely acknowledge both my supervisors for spending their valuable time in fruitful discussion on my research.

I place my sincere thanks to my friends for their cooperation and assistance. Thanks for their willingness in spending time to have wonderful discussion on my work.

My deep sense of gratitude goes to my family for their mental and financial support throughout all these years.

Ervin Gubin Moung
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ASBTRACT

Comparison of Face Recognition Techniques: The Effects of Features and Parameters Setting

Face recognition is an important biometric application. In this thesis, a comparison of two common techniques for face recognition is carried out under the same conditions. The first technique is the Principal Component Analysis (PCA) while the second is Linear Discriminant Analysis (LDA). In addition, the performance of PCA and PCA (with Radon) was also carried out. The Euclidean distance is used as the matching criteria. An investigation of the effect of the parameters of PCA on the performance of the face recognition system is carried out. First, it was found that the number of eigenvalues used affects the recognition rates of the system. The maximum number of eigenvalues used is 300. The equal correct rates increases from 1 until 40 to 80 eigenvalues used then become steady afterwards regardless of the image size used. Second, it was found that the higher the number of training images per person the lower the false acceptance rate. Third, the image size used effect the recognition rate when a fixed number of eigenvalues used. However, different image size has their own their optimum number of eigenvalues to achieve highest equal correct rate. When optimum eigenvalues used, their recognition rate did not vary significantly. A comparison of performance, time and resource used by all face recognition system is presented. Four individual systems are compared; PCA, PCA with Radon, LDA, and LDA with Radon. Each individual system gives recognition rate of 89%, 88%, 94%, and 92% respectively with LDA outperform the other three techniques. It was found that no improvement on recognition rate when PCA and LDA use the Radon Transform features as input showing that applying Radon Transform on properly normalized frontal image does not boost the recognition performance. When compared the individual system to the data fusion system, it was found out that data fusion system gives better recognition rate than all the individual face recognition system. Fusion of PCA, LDA, and LDA with Radon give the best recognition performance, giving 98% correct recall and reject rate, and uses 62.8 second process time and 22.2 MB space.

ASBTRAK

Pengesanan wajah adalah satu aplikasi biometrik yang penting. Dalam tesis ini, perbandingan antara dua teknik umum untuk pengesanan wajah dijalankan di bawah keadaan yang sama. Teknik pertama adalah "Principal Component Analysis" (PCA) manakala yang kedua adalah "Linear Discriminant Analysis" (LDA). Di samping itu, perbandingan prestasi PCA dan PCA (dengan Radon) juga telah dijalankan. "Euclidean Distance" digunakan sebagai kriteria perpadanan. Penyiasatan terhadap kesan parameter PCA pada prestasi sistem pengesanan wajah telah dijalankan. Pertama sekali, bilangan "eigenvalues" yang digunakan memberi kesan terhadap kadar pengesanan sistem. Bilangan maksimum "eigenvalues" yang digunakan ialah 300. Kadar pengesanan meningkat dari satu sehingga 40 ke 80 "eigenvalues" yang digunakan dan kemudiannya menjadi stabil tanpa mengira saiz imej. Kedua, semakin tinggi bilangan imej "training" untuk satu orang lebih rendah kadar penerimaan salah. Ketiga, saiz imej yang digunakan memberi kesan terhadap kadar pengesanan apabila bilangan "eigenvalues" yang digunakan adalah tetap. Walau bagaimanapun, saiz imej berlainan mempunyai bilangan "eigenvalues" optimum tersendiri untuk mencapai kadar pengesanan tertinggi. Apabila bilangan "eigenvalues" optimum digunakan, perbezaan kadar pengesanan adalah tidak ketara antara imej saiz yang berlainan. Perbandingan prestasi, masa dan sumber yang digunakan oleh semua sistem pengesanan wajah dibentangkan. Empat sistem individu PCA, PCA (dengan Radon), LDA, dan LDA (dengan Radon) telah dibandingkan. Setiap sistem memberikan kadar pengesanan setinggi 89%, 88%, 94%, dan 92% dengan LDA mengatasi prestasi tiga teknik yang lain. Tiada peningkatan pada kadar pengesanan apabila PCA dan LDA menggunakan "Radon Transform" sebagai input dan ini menunjukkan bahawa aplikasi Radon Transform terhadap imej wajah depan yang "normalized" tidak meningkatkan prestasi pengesanan. Sistem gabungan data memberi kadar pengesanan yang lebih baik apabila dibandingkan dengan sistem individu. Gabungan PCA, LDA, dan LDA (dengan radon) memberi prestasi pengesanan yang terbaik, memberikan 98% peratus kadar penerimaan dan penolakan yang betul, dan menggunakan 62.8 saat masa proses dan 22.2 MB ruang.

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LIST OF ABBREVIATIONS

1D	One Dimension
1IPP	One image per person
2D	Two Dimension
2DPCA+SVD-U	Two-Dimensional Principal Component Analysis and Singular Value Decomposition
2IPP	Two images per person
3D	Three dimension
3IPP	Three images per person
AdaBoost	Adaptive Boosting
ANN	Artificial Neural Network
AR	Aleix Martinez and Robert Benavente
ARENA	Memory-based algorithm for face recognition
AT&T	American Telephone & Telegraph
BIC	Bayesian intra/extrapersonal classifier
CAS-PEAL	Chinese Academy of Sciences-Pose, Expression, Accessories and Lighting
CBCL	Center for Biological and Computational Learning
CC	Correct Classification
CCTV	Closed Circuit Television
CMU	Carnegie Mellon University
CPU	Central Processing Unit
CVL	Computer Vision Laboratory
DCT	Discrete Cosine Transform
DNWT	Discerete NonSeparable Wavelet Transform
EBGM	Elastic Bunch Graph Method
ECR	Equal Correct Rate
ESSEX	University of Essex face database
FaceDB60	Face Database containing 60 individuals
FaceDB100	Face Database containing 100 individuals
FaceIt	Commercial face recognition software

FaceVideoDB	Video based face database
FAR	False Acceptance Rate
FERET	Face Recognition Technology
FLD	Fisher Linear Discriminant
FRR	False Rejection Rate
GP	Genetic Programming
GTFD	Georgia Tech Face Database
HMM	Hidden Markov Model
HP	Hewlett-Packard
HSV	Hue Saturation Value
I(2D)^{2}PCA	Incremental Two-Dimensional Two-Directional Principal Component Analysis
ICA	Independent Component Analysis
ID	Identification
IDU	A real time face detection, tracking and identification system
jpeg	Join Photographic Experts Group
KFDB	Korea Face Database
KLT	Karhunen-Loève transform
KPCA	Kernel Principal Component Analysis
KTD	Known testing database
LBP	Local Binary Patterns
LDA	Linear Discriminant Analysis
LFA	Local Feature Analysis
LLE	Locally Linear Embedding
LPCA	Linear Principal Component Analysis
LS-SVM	Least Square Support Vector Machine
MLPCA	Multilinear Principal Component Analysis
MID	Mugshot Identification Database
MIT	Massachusetts Institute of Technology
MoBo	Motion of Body
MPEG	Moving Picture Experts Group
MRTD	Machine Readable Travel Documents

ND HID	Notre Dame Human Identification Database
NFL	Nearest Feature Line
NIST	National Institute of Standard and Technology
OCPCA	Orthogonal Component Principal Component Analysis
OS	Operating system
PC	Personal computer
PCA-SIFT	Principal Component Analysis and Scale Invariant Feature Transform
PCA	Principal Component Analysis
PCAW	Principal Component Analysis based whitening transform
PDA	Personal digital assistant
PIE	Pose, Illumination and Expression
ppm	Portable PixMap
RAM	Random-access memory
RGB	Red Green Blue
RT&KPCA	Radon transform plus Kernel Principal Component Analysis
RT&LPCA	Radon transform plus Linear Principal Component Analysis
SFFS	Sequential Floating Forward Selection
SPCA	Statistical Principal Component Analysis
SVM	Support Vector Machine
Tcpara	Threshold tuning parameter
TV	Television
UCSD	University of California San Diego
ULLELDA	Unified Locally Linear Embedding and Linear Discriminant Analysis Algorithm
UMIST	University of Manchester Institute of Science and Technology
UTD	Unknown testing database
XM2VTS	Multi modal face database
YCbCr	Luminance; Chroma Blue; Chroma Red

LIST OF SYMBOLS

Φ_i	In PCA algorithm, this is the zero mean face vector, obtained by subtracting the Γ_i with Ψ
Γ_i	In PCA algorithm, this is the N^2-dimensional vector representation of an image
∞	Infinite
λ	In PCA algorithm, this is the eigenvalue of A^TA
λ	In LDA algorithm, this is the eigenvalue
μ_i	In LDA algorithm, it denote the mean face of each person P_i
Ω	In PCA algorithm, this is the low dimension vector, a new representation of a training image
ρ	In Radon Transform, ρ is defined as the distance of the line from the origin
Ψ	In PCA algorithm, this is the mean face vector obtained from the training database set
θ	In Radon Transform, θ is the angle from the horizontal $x-axis$
θ_{tc}	Distance threshold value
A	In PCA algorithm, this is the collection of Φ obtained from the training database set
C	In PCA algorithm, this is the covariance matrix of AA^T
$E_{largest}$	The largest distance threshold value, θ_{tc}, boundary
E_{min}	The minimum value from matrix E_r
E_r	A set of Euclidean distance scores
$E_{smallest}$	The smallest distance threshold value, θ_{tc}, boundary
I	An N by N dimension image
i	In PCA algorithm, the maximum number of i is the total number of training images which is M
i	In LDA algorithm, the maximum number of i is the total number of images per person have which is n

j	In PCA algorithm, the maximum number of j is the total number of eigenvectors obtained. For the matrix $\boldsymbol{AA^T}$, the maximum number of j is N^2. For the matrix $\boldsymbol{A^TA}$, the maximum number of j is M.
K	In PCA algorithm, this is the number of eigenvector used in face recognition system with $K \leq M$
k	In LDA algorithm, the maximum number of k is the total number of eigenvectors obtained, m
M	The total number of images in the training database
m	In LDA algorithm, this is the total number of eigenvectors obtained.
N	The width or height of a square image in pixel unit
n	In LDA algorithm, it denote the total number of images per person
P_C	In LDA algorithm, it denote the person in the training database where C denote total number of persons in the training database
S	In Radon Transform, S is defined as line integral in the image
S_B	In LDA algorithm, this is the between-class scatter matrix
S_W	In LDA algorithm, this is the within-class scatter matrix
u_i	In PCA algorithm, this is the eigenvector of covariance matrix $\boldsymbol{C}$
v_j	In PCA algorithm, this is the eigenvector of $\boldsymbol{A^TA}$
v_k	In LDA algorithm, this is the eigenvector
w_j	In PCA algorithm, this is the weight value of Φ_I, when multiplying u_j^T with Φ_I

CHAPTER 1

INTRODUCTION

1.1 Overview of Face Recognition

Face recognition is one of the biometric methods used to identify a person by the features of his/her face. Face recognition has received a considerable attention in recent years both from the industry and research communities (International Biometric Group, 2009). The importance of face recognition arises from the fact that a face recognition system does not require the cooperation of an individual while most biometric system needs such cooperation. Among the popular biometric technologies, facial features and face recognition scored the highest compatibility in a machine readable travel documents (MRTD) system based on a number of evaluation factors (see Figure 1.1) and is the most successful form of human surveillance (Lu, 2003).

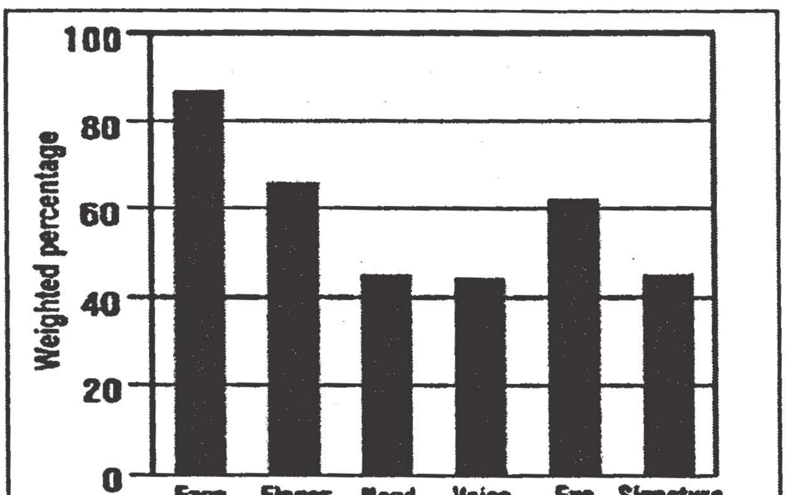

Figure 1.1: Comparison of various biometric features based on MRTD Source: (Lu, 2003)

Facial recognition technology is one of the fastest growing fields in the biometrics industry. Interest in face recognition is being fueled by the availability and the low cost of video hardware, the ever-increasing number of video cameras being placed in the workspace and the noninvasive aspect of facial recognition systems.

The goal of the face recognition is to identify or verify the persons present in the shots based on their facial features, despite of wide variations in pose, facial expressions and illumination changes (Zhao, 2003). But automatic face recognition systems need to overcome various problems like pose invariance, illumination invariance, facial expression changes etc. Many methods of face recognition have been proposed during the past 30 years (Zhao, 2003). As a result, the current status of face recognition technology is well advanced. Various novel techniques have been proposed ranging from the traditional template matching to the latest three-dimensional techniques. Although over 30 years of extensive research has been conducted in this area, there still exist open research issues, the performance of the current algorithms being still far from that of human perception.

1.2 Applications of Face Recognition

Face recognition has received considerable interest as a widely accepted biometric because of the ease in collecting face images of persons. Although very reliable methods of biometric personal identification exist, for example, fingerprint analysis and retinal or iris scans, these methods rely on the cooperation of the participants, whereas a personal identification system based on analysis of frontal or profile images of the face is often effective without the participant's cooperation or knowledge (Zhao, 2003).

Face recognition is being used in various applications like crowd surveillance, criminal identification, and criminal record, access to restricted area etc. Nowadays, the necessity for personal identification in the fields of private and secure system make face recognition one of the main fields among other biometric technology, such as fingerprint identification, hand geometry identification, iris identification etc. Figure 1.2 shows that facial recognition takes 11.4% of the total biometric market. Table 1.1 shows the typical applications of face recognition.

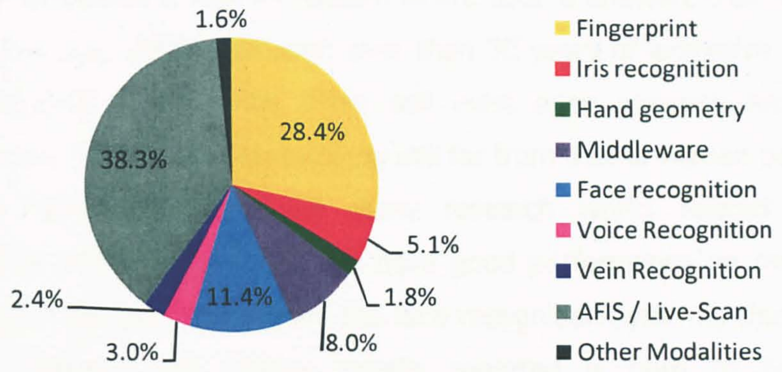

Figure 1.1: The ratio of different biometric method in market
Source: (International Biometric Group, 2009)

Table 1.1: Applications of face recognition

Area	Specific applications
Entertainment	Video game, virtual reality, training programs
	Human-robot-interaction, human-computer-interaction
Smart cards	Drivers' licenses, entitlement programs
	Immigration, national ID, passports, voter registration
	Welfare fraud
Information security	TV Parental control, personal device logon, desktop logon
	Application security, database security, file encryption
	Intranet security, internet access, medical records
	Secure trading terminals
Law enforcements and surveillance	Advanced video surveillance, CCTV control
	Portal control, post event analysis
	Shoplifting, suspect tracking and investigation

Source: (Zhao, 2003)

1.3 Motivation

There are many biometrics methods that can be used to identify a person such as face, fingerprint, hand, voice, eye and signature. Among these biometric methods, the face is the feature which best distinguishes a person and face recognition is a widely accepted biometric because of the ease in collecting face images of persons

and can be use as biometric trait for system where user is unaware that he or she is being subjected (Lu, 2003). Although over than 30 years of extensive research has been conducted in this area, there still exist open research issues, the performance of the current algorithms being still far from that of human perception (Zhao, 2003). Nowadays, there are many research works related to face recognition. Most of the work claimed to have good performance on recognition rate but no benchmark test to compare the face recognition systems, thus making a comparison between the various results reported is hard to be made. Comparison between various face recognition systems is important so that we can know which system performs better than others under the same test condition.
This thesis will focus on preparing a benchmark test for evaluating common reported global based face recognition approach. The test bed and test criteria chosen are based on the literature review of face recognition.

1.4 Problem Statement

Currently there are many face recognition research reports published. Most of them used different database and different criteria for their experiments, thus a comparison between the various results reported is hard to be made. In addition, from all the face recognition reports published, there are no comparisons made for resources used by the published system.

1.5 Objectives

The main objectives of the thesis are:

i. To establish a test bed and test criteria for evaluating common reported global approach. The test bed and test criteria chosen are based on the literature review.
ii. To investigate fusing strategies for combining several global approaches.

1.6 Scope

The scopes of the thesis are:

i. All the face images used for experiments are still image type.
ii. There is only one face per image.

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