AGE INVARIANT FACE RECOGNITION SYSTEM USING AUTOMATED VORONOI DIAGRAM SEGMENTATION

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ABSTRACT

One of the challenges in automatic face recognition is to achieve sequential face invariant. This is a challenging task because the human face undergoes many changes as a person grows older. In this study we will be focusing on age invariant features of a human face. The goal of this study is to investigate the face age invariant features that can be used for face matching, secondly is to come out with a prototype of matching scheme that is robust to the changes of facial aging and finally to evaluate the proposed prototype with the other similar prototype. The proposed approach is based on automated image segmentation using Voronoi Diagram (VD) and Delaunay Triangulations (DT). Later from the detected face region, the eyes will be detected using template matching together with DT. The outcomes, which are list of five coordinates, will be used to calculate interest distance in human faces. Later ratios between those distances are formulated. Difference vector will be use in the proposed method in order to perform face recognition steps. Datasets used for this research is selected images from FG-NET Aging Database and BioID Face Database, which is widely being used for image based face aging analysis; consist of 15 sample images taken from 5 different person. The selection is based on the project scopes and difference ages. The result shows that 11 images are successfully recognized. It shows an increase to 73.34% compared to other recent methods.

ABSTRAK

Salah satu cabaran pemadanan muka secara automatik adalah untuk mencapai turutan muka yang tidak berubah mengikut masa. Faktor utama yang menyumbang kepada permasalahan ini adalah kerana wajah manusia mengalami banyak perubahan sepanjang proses peningkatan usia. Kajian ini akan member tumpuan kepada ciri-ciri pada wajah manusia yang tidak berubah mengikut umur. Objektif kajian ini adalah untuk menyiasat ciri-ciri pada wajah yang tidak berubah mengikut umur dan boleh digunakan untuk memadankan muka, objektif kedua adalah untuk membina prototaip system pemadanan wajah yang teguh kepada perubahan penuaan wajah dan akhir sekali adalah untuk menilai prototaip yang dicadangkan dengan prototaip lain yang hampir serupa. Kajian yang dicadangkan mengunakan segmentasi imej secara automatik menggunakan *Voronoi Diagram (VD)* dan *Delaunay Triangulations (DT)*. Kemudian daripada imej wajah yang dikesan, mata akan dikesan menggunakan *Template Matching* bersama-sama dengan DT. Hasilnya, iaitu lima koordinat, akan digunakan untuk mengira jarak cirri-ciri penting dalam muka manusia. Kemudian antara jarak-jarak ini akan dikira. *Difference Vector* akan digunakan dalam kaedah yang dicadangkan untuk melaksanakan langkah-langkah pengiktirafan muka. Dataset yang digunakan di dalam kajian ini merupakan imej-imej yang dipilih dari Pangkalan Data Penuaan FG-NET dan Pangkalan Data Wajah BioID, yang secara meluas diterima pakai bagi analisis imej muka berasaskan penuaan. 15 imej sampel yang diambil daripada 5 orang yang berbeza. Pemilihan adalah berdasarkan skop projek dan perbezaan umur. Hasilnya menunjukkan bahawa 11 imej berjaya dicam. Ia menunjukkan peningkatan kepada 73,34% berbanding dengan kaedah lain baru-baru ini.

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LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
DT	-	Delaunay Triangulations
EU	-	Euclidean
FEBFRGAC	-	Extraction Based Face Recognition, Gender And Age Classification
FERET	-	The Facial Recognition Technology Database
FRVT 2002	-	Face Recognition Vendor Test 2002
FRVT 2006	-	Face Recognition Vendor Test 2006
GB	-	Giga Byte
GOP	-	Gradient Oriented Pyramid
GWT	-	Gabor Wavelet Transform
HDD	-	Hardisk
HP	-	Hewlett Packard
HSI	-	Hue Saturation Intensity value
ICAO	-	International Civil Aviation Organization
JPG/JPEG	-	Joint Photographic Experts Group
LDA	-	Linear Discriminant Analysis
MBE 2010	-	Multiple Biometric Evaluation
MFDA	-	Multi Features DiscriminatAnalysis
MLBP	-	Multi scale local binary pattern
NIST	-	National Institute of Standards and Technology

PCA	-	Principle Component Analysis
RFID	-	Radio Frequency Identification
RGB	-	Red, Green and Blue
SFS	-	Shape From Shading
SIFT	-	Scale Invariant Feature Transfer
SVM	-	Support Vector Machine
UDP	-	Unsupervised Discriminant Projection
VD	-	Voronoi Diagram
WLBP	-	Walsh-Hadamard transform encoded local binary patterns

CHAPTER 1

INTRODUCTION

Personal verification and identification is an actively growing area of research nowadays. Face, voice, lip movements, hand geometry, odor, gait, iris, retina, fingerprint are the most commonly used authentication methods. These physiological and behavioral characteristics are known as biometrics, contributed significant advantages compared to the traditional authentication techniques (Ramesha *et al.*, 2010). The high demand of the progress in this field is due to the growing role of the technology in the modern society. As a result, numbers of application appeared in daily tasks such as online electronic commerce, automated factory machines and building security system.

Face recognition is one of the biometrics approaches to identify individuals by the features of the face. Research in this area has been conducted for more than 30 years but only become famous for the past 10 years (Li *et al.*, 2011); therefore, currently the face recognition technology is well advanced. Wide range of applications has been using this approach such as security and surveillance system, human computer interaction, image retrieval, criminal identification, etc. In general, the approach will be using a pre-stored image database where later the face recognition system will be able to identify or verify the person from the captured image or another source of images to the one in the database. The age and gender of a person are grouped by visual observation of still images where it is difficult for the computer vision. Hence, there comes the need to discover the age and gender related area for further studies. However, in this project, we will be focusing only on age related issues.

1.1 BACKGROUND OF THE PROBLEM

Face recognition across the ages is a significant problem and has many applications such as passport photo verification, image retrieval, surveillance (Ling *et al.*, 2007), etc. This is a challenging task because the human face undergoes many changes as a person grows older. Each person has different facial features in many aspects, including facial texture (e.g. wrinkles), shape (e.g. weight gain), facial hair, presence of glasses, and exposure to sunlight (Ling *et al.*, 2010), that make us different to each other. In addition, the image acquisition environments also have an effect on the images captured.

The performance of face recognition systems cannot challenge with the sequential changes over a period of time. Law enforcement agencies such as crime and record bureau regularly require matching a probe image with the individuals in the missing person database (Singh *et al.*, 2007), or a customs need to compare new photo to the previous photo during the passport renewal process. In such applications, there are many significant differences between the facial features of probe and gallery image due to age variation. For example, if the age of the probe image is 15 years old and the gallery image of the same person is 5 years old, an existing matching system is ineffective and might not produce the expected result. Figure 1 shows several typical images with different age gaps.

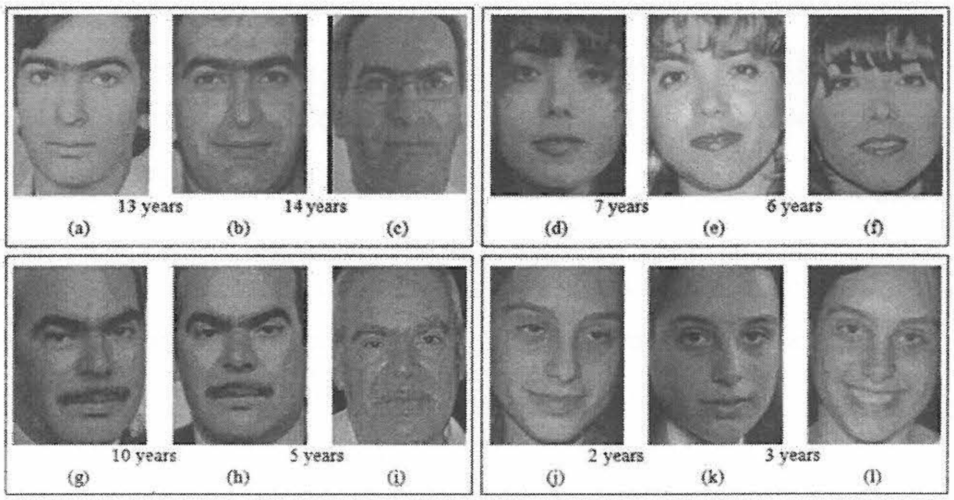


Figure 1.1 Typical images with age differences. Source images are from the FG-NET Aging Database, http://www.cut.ac.cy/members/fgnet.

One way to overcome this challenge is to regularly update the database with recent images or templates (Singh *et al.*, 2007). However, this method is not suitable for applications such as border control, homeland security and missing person identification. To address this issue, researchers have proposed several techniques which later we will discuss in Chapter 2.

1.2 PROBLEM STATEMENT

Determining age-invariant features of a human face is a difficult task since human face facing significant changes across time. Still this task is necessary in many applications, especially those that require checking whether the same person have issued multiple government documents (e.g. passport, identification card and driving license) that include facial images (Li *et al.*, 2011).

In this project, we will study on standard features or also being referred as age-invariant features of a human face which later can be used as target points for face recognition process. To recognize the face, we will come out with a prototype to determine whether the images come from the same person, in whom an individual is identified from a large gallery of individuals; in this project we will be using FG-NET Aging and BioID face database as our dataset.

1.3 PROJECT OBJECTIVES

The objectives of the project are:

1. To investigate age-invariant features of a human face;
2. To develop a prototype for face recognition system based on the selected features; and
3. To test and evaluate the accuracy of the proposed prototype by comparing with other similar face recognition prototypes.

1.4 RESEARCH QUESTIONS

The main questions this research motivates to answer are as follows:

1. What are the features of human face that are not changing across age?
2. How to develop a prototype of the face recognition system?
3. What is the effectiveness of the proposed prototype with other similar face recognition prototype?

1.5 PROJECT AIMS

The aim of this study is to investigate the age-invariant features of a human face and later develop a prototype of face recognition systems implementing the selected features. The prototype will be tested using FG-NET Aging and BioID face database as datasets in our experiments.

1.6 SCOPES OF THE STUDY

The scopes for this study focus on:

1. Only three (3) age-invariant features will be implemented in the prototype;
2. Image format use for this project will be in Joint Photographic Expert Group (.jpg and .jpeg) only;
3. Images sample will be a face image with frontal faces only; and
4. The prototype can dealt with color and grayscale images;
5. Sample face images will be taken from FG-NET Aging and BioID face databases;
6. Age group of the sample images is 18 years old and above.

CHAPTER 2

LITERATURE REVIEW

Human faces are varied with the age group; baby, children, adult and old age. In this chapter, we will be discussing on the invariant features of human faces. The need of automated face recognition has been important yet challenging problem. This challenge can be due to range of variations such as pose, illumination, expression, and aging. Among these variations, aging factors is now raised attention in the face recognition community. Designing an age invariant face recognition are crucial in many applications, especially those that require checking on the person verification (e.g. passports, driver license) that include facial images. Despite numerous research efforts has been conducted to study in this area for the past 30 years, most of the works focus on age estimation and age simulation from the face variations. However for the past 10 years, the face recognition based on age barrier seems to take researchers' interest which later will be discussed in this chapter.

2.1 FACE VARIATIONS BY AGE

According to Marquardt Beauty Analysis, California, the most common variations of human faces can be grouped into three groups which are age, sex and geographical (ethnicity). In this project we will be focusing only on the age factor. The analysis also stated that the periods of ages can be randomly grouped into four main categories which are babies, children, adults and old age. Table 2.1 explains further on the variations of the face across the age. Just like every other aspect of human existence the face also varies with age. To state that the face changes with age is barely news.

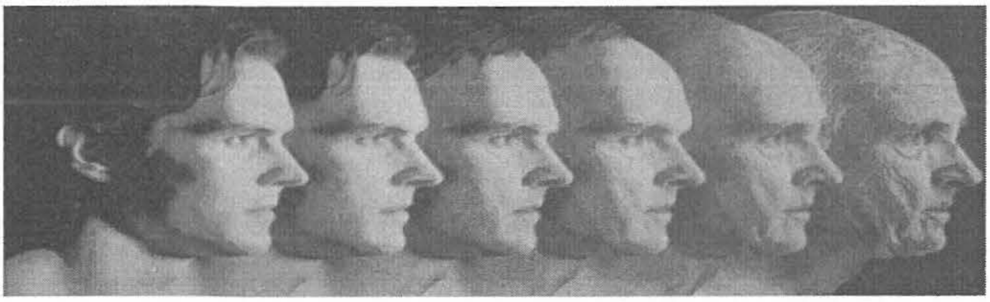
Table 2.1: Descriptions on human face variations across the age (MAB, 2005)

Group	Description
Baby	Major personal visual attractiveness. Age group: 1 - 24 months. Bigger eyes in proportion to its face. Rounder face. Plumper cheeks. Larger head in portion to its face. Short, flat eyebrows. Short, relatively small, turned up nose. 

Table 2.1: Descriptions on human face variations across the age (MAB, 2005) (continue)

Group	Description
Children	Less attractive. Age group: 3 – 11 years Freckles or acne. Flat eyebrows, fuller than the child. Ears that appears oversized. Nose generally small, short and wide. Relatively flatter and less defined cheeks 
Adult	Attractive peak. Age group: 14 to 24 years. Static facial form. 

Table 2.1: Descriptions on human face variations across the age (MAB, 2005) (continue)

Group	Description
Old Age	Age group: 25 years and above The face begins to gradually matures/ aging The cheeks sag inferiorly resulting the appearance of jowls The corners of the mouth move inferiorly resulting in a slight frown look The tissue around the eyes sag inferiorly The eyelids, upper and lower, themselves sag inferiorly The tissue of the forehead drifts inferiorly, creating wrinkles and dropping the eyebrows downward and giving them a flatter appearance The nose may lengthen and move the tip inferiorly The nose may develop a small to pronounced dorsal hump The tip of the nose may enlarge and become bulbous Generalized wrinkling of the face may occur 

Human face undergoes significant changes as the person grows older. The facial features of human are different compared to each other. Singh *et al.* in their study divided the human age into three age groups for testing purposes which are 1-18 years old, 19-40 years old and beyond 41 years old. They strongly believe that face development depends on the ages of a person. For example, development in muscles and bone structure caused major changes in the face at the age of 1-18 years old. From 19-40 years old, the growth rate is comparatively lower, whereas after 40 years old, wrinkles and skin loosening cause major change in facial features and appearance (Singh *et al.*, 2007).

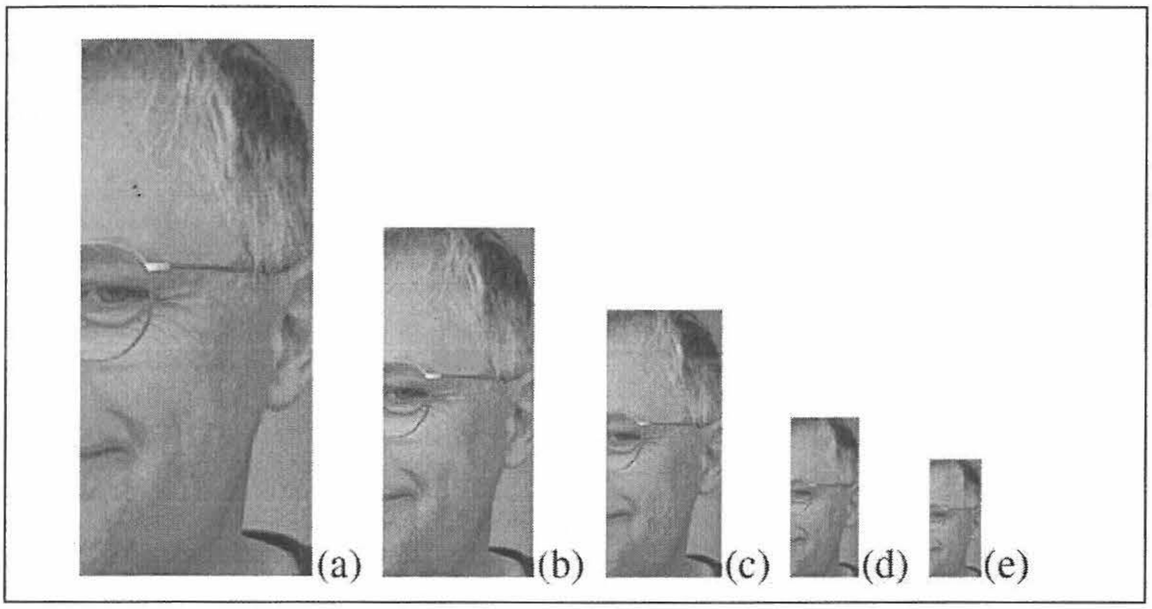


Figure 2.1 Perception of wrinkles at different resolution (Ling *et al.*, 2007)

Figure 2.1 illustrate the perception of wrinkles at different resolution (in pixels) of a face image at age 50. Image (a)is the original image with height = 347, image (b) with height = 207, image (c) with height = 160, image (d) with height = 96, and image (e) with height = 72 pixels. From Figure 2.1, we can clearly see the wrinkles seem to be disappearing when the resolutions decreases The effects of wrinkles to the face normalcy are reduced by the image resolution and the natural distribution of the wrinkles itself. Kwon (1999), believe that wrinkles are hardly perceptible for images with low resolution. The distribution of wrinkles on human faces is known to be inidentical. For example, Boissieux *et al.* (2007), concluded eight wrinkles maps from the qualitative data from L'Oreal. From the study, wrinkles appear frequently on the forehead and cheeks, which are not important for face recognition. This means that most regions with heavy wrinkles can be ignored for face recognition.

Earlier study of facial growth conducted by Pittenger and Shaw (1975), has shown that face profile (e.g. boundary shapes, eye locations) are relatively stable at the age of 18 years old onward. S. Akazaki *et al.* (2003), stated that wrinkles are one of the most important factors for the visual perception of age whereas the width and depth of wrinkles grow roughly linearly with age.

Considering that entire face with the high structural complexity easily changes across time, Xu *et al.* (2011) decided to only use periocular region as one of the age invariant features for face recognition. This is because the periocular region changes practically smaller over time due to the shape and location of the eyes remain largely unchanged compared to mouth, nose, chin, cheek, etc., which are more vulnerable to changes given by a loosened skin (Masoro and Austad, 2010). These clarify why most of the researchers select eyes location as a reference point for face recognition.

2.2 IMAGE SEGMENTATION

Image segmentation can be described as a process of partitioning a digital image into multiple segments. The goal of image segmentation is to simplify and/ or change the representation of an image into something that is more meaningful and easier to analyze (Shapiro G. and Stockman C., 2001). Image segmentation is normally used to locate objects and boundaries (e.g. lines, curves, etc) in images. The result from this process is a set of segments extracted from the entire image which later can be used for object recognition, boundary estimation, image editing, image database lookup etc (Jepson A. D. and Fleet D. J., 2007). While in this research, image segmentation is mainly implemented to detect the face region for the "*face localization*" step.

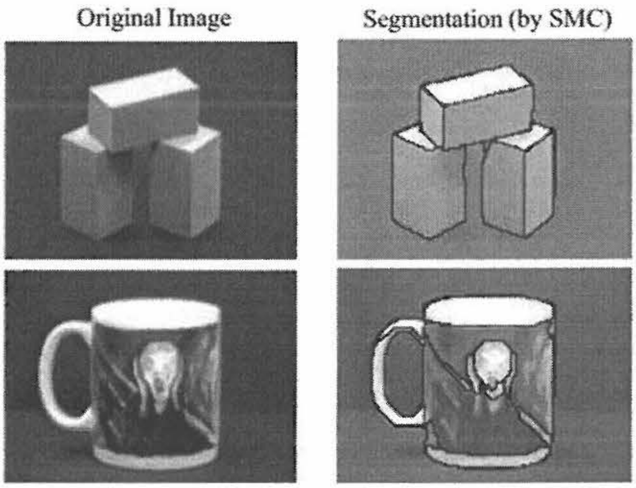


Figure 2.2 Simple Scenes for Image Segmentations (Jepson A. D. and Fleet D. J., 2007)

Figure 2.2 shows a simple example of image segmentation using Spectral Embedding and Min-Cut (SMC) algorithm. It clearly describes that segmentations of