Development of Background Subtraction Algorithm for Biometric Identification

by

AKBAH A. KHALIFA
(0630610100)

A thesis submitted
in fulfillment of the requirements for the degree of
Master of Science (Mechatronic Engineering)

SCHOOL OF MECHATRONIC ENGINEERING
UNIVERSITI MALAYSIA PERLIS

2008

ACKNOWLEDGMENTS

I would like to express my sincere appreciation to my supervisor Assoc. Prof. Dr. Kenneth Sundaraj for his instructive comments, patience and support throughout my research work. He provided counsel and assistance that greatly enhanced my studies and knowledge. A big thanks to Dr. Zunaidi Ibrahim who is the co-supervisor of this project. I would like to thank my brothers and sisters for their emotional support and belief in me.

Last but not the least, I would like to express my greatest appreciation to all the people who have helped me in my research work.

ABSTRAK

PEMBANGUNAN ALGORITMA PENOLAKAN LATAR BELAKANG UNTUK PENGENALPASTIAN MUKA BIOMETRIK

Di dalam thesis ini, diperkenalkan satu kaedah baru yang lebih baik untuk sistem automatik pengenalpastian muka. Persegmenan objek baru ataupun dinamik dalam satu imej boleh dicapai melalui teknik penolakan latar belakang ataupun persegmenan latar depan. Ini adalah suatu langkah awal kritikal dalam kebanyakan aplikasi penglihatan komputer dalam domain seperti sistem pengawasan dan interaksi manusia-komputer.

Sistem yang dicadangkan mengandungi tiga tahap. Dalam tahap yang pertama, penolakan latar belakang digunakan untuk menangani masalah perubahan pencahayaan, bayang-bayang, pantulan, persamaan warna latar depan dengan warna latar belakang dan latar belakang dinamik (e.g. paparan video aktif ataupun gerakan pohon ditiup angin). Satu kaedah dicadangkan untuk memodel latar belakang yang berasaskan setiap pixel, mudah suai masa dan menggunakan gabungan Gaussian dalam kombinasi pixel jiran and warna tak varian. Kombinasi in secara sendirinya adalah baru. Dalam tahap kedua, pengurangan ralat dalam imej untuk meningkatkan kejituan dijalankan dengan munggunakan penapisan morfologi yang menghasilkan satu imej dwi-warna. Di dalam tahap ketiga pula, satu teknik yang baru untuk mencari posisi kepala di dalam imej dan mengekstraknya untuk pengesanan dan pengenalpastian.

Pengujian algorithma dalam keadaan pencahayaan and persekitaran berbeza telah dijalankan. Keputusan eksperimen menunjukkan bahawa kaedah yang digunakan mempunyai ketahanan tinggi terhadap masalah-masalah yang dibangkitkan oleh penyelidik terdahulu tanpa mengorbankan prestasi masa-nyata yakni menjadikannya sesuai untuk banyak rangkaian aplikasi video yang memerlukan pengesanan dan pengenalpastian.

Hasil eksperimen pada aplikasi masa sebenar menunjukkan kekuatan, keterpercayaan dan kecekapan pada pendekatan yang diusulkan; hasil eksperimen ini dapat mencari dan mengekstrak muka manusia dalam 98% daripada eksperimen, dengan kemampuan untuk mencari muka untuk pelbagai kelamin, warna kulit dan pemakaian kepala. Algoritma yang diusulkan dapat menghasilkan 30 hingga 35 FPS dalam saiz citra 320×340 pixel, di mana ianya lebih baik daripada aplikasi masa sebenar yang lain.

ABSTRACT

DEVELOPMENT OF BACKGROUND SUBTRACTION ALGORITHM FOR BIOMETRIC IDENTIFICATION

This thesis presents an improved approach for an automatic face detection system. Segmentation of novel or dynamic objects in a scene can be achieved using background subtraction or foreground segmentation. This is a critical early step in most computer vision applications in domains such as surveillance and human-computer interaction.

The proposed system consists of three parts. In the first part, the use of background subtraction algorithm to deal with the problem of lighting changes, shadows and repetitive motions. All previous implementations fail to handle properly one or more common phenomena, such as global illumination changes, shadows, inter-reflections, similarity of foreground color to background and non-static backgrounds (e.g. active video displays or trees waving in the wind). The proposed method is a background model that uses per-pixel, time-adaptive and Gaussian mixtures in the combined input space of pixel neighborhood and luminance invariant color. This combination in itself is novel. In the second part, another technique known as morphological erosion and dilation operators are used to remove the noise in the resulting binary image to improve the accuracy. The third part is accomplished by using a new technique to locate the face position in the image and extract it for recognition and identification purposes.

The algorithm has been tested in several different lighting conditions and environments. The experimental results show that the method possesses much greater robustness to problematic phenomena than the prior state of the art methods, without sacrificing real-time performance, making it well-suited for a wide range of practical applications in video events which requiring detection in real-time.

The experimental results in real time applications show the robustness, reliability and efficiency in the proposed approach; they can accurately detect and extract human face 98% *of the time, with the ability to detect the face of different types of people gender, skin color and head attire. The proposed algorithm can be executed at* 30 *to* 35 *FPS for an image size of* 320×240 *pixel, which is much better when compared with any other real time applications.*

Contents

List of Tables

List of Figures

List of Abbreviations

2D	Two Dimension
3D	Three Dimensional
AFP	Automatic Face Processing
AVI	Audio Video Interleave - An audio-video standard designed by Microsoft
BG	Background
CCD	Charge Couple Device (chip)
CCTV	Closed-circuit Television
CMOS	Complementary Metal Oxide Semiconductor
CMU	Carnegie Mellon University
Com	Common (System Ground)
CTS	Clear To Send
DCD	Data Carrier Detect
DCE	Data Communication Equipment
DSR	Data Set Ready
DTE	Data Terminal Equipment
DTR	Data Terminal Ready
EIA	Electronics Industries Association
FPS	Frames Per Second
G	Gradient

GHz	Gigahertz
H	Horizontal
IBM	International Business Machines
ID	Identification / Identity Card
ITU	International Telecommunication Union
LED	Light Emitting Diode
LFA	Local Feature Analysis
MD	Mahalanobis Distance
MHz	Megahertz
MIT	Massachusetts Institute of Technology
MoG	Mixture of Gaussian
NA	Not Available
OB	Object
OS	Operator System
PC	Personal Computer
PCB	Printed Circuit Board
RGB	Red-Green-Blue (Color Space)
RI	Ring Indicator
RS-232	Recommended Standard 232 (computer serial interface)
RTS	Request To Send
RxD	Receive Data
SH	Shadow
SMPTE	Society of Motion Picture and Television Editors
TI	Texas Instruments

TV	Television
TxD	Transmit Data
USB	Universal Serial Bus
V	Vertical
W4	Who? When? Where? What? (system for detecting and tracking people)
YUV	Luminance-Bandwidth-Chrominance (Color Space)

Chapter 1

Introduction

1.1 Overview

Biometrics consist of automated methods of recognizing a person based on a physiological or behavioral characteristic. Among the features measured are face recognition, finger-print, hand geometry, handwriting, irises and voice patterns. Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions. As the level of security breaches and transaction fraud increases, the need for highly secure identification and personal verification technologies is becoming apparent.

Biometric based solutions are able to provide for confidential financial transactions and personal data privacy. The need for biometrics can be found in federal, state and local governments, in the military and in commercial applications. Enterprise-wide network security infrastructures, government IDs, secure electronic banking, investing and other financial transactions, retail sales, law enforcement and health, social services are already benefiting from these technologies.

Face recognition for biometric identification is a fairly young technology compared to other biometrics. Research in this field has been going on for decades, but it has been

in the last 10 to 15 years that the greatest advances have taken place.

Biometric devices for face recognition consist of,

- A sensor or camera device.
- Software that converts the image information into digital form and extracting biometric data.
- A database that stores the biometric data for comparison.

Generally speaking, face recognition works by first obtaining an image of a person. This process is usually accomplished by a video camera of a certain resolution and at a certain number of frames per second. Higher quality cameras will of course produce more accurate results. Then a computer software analyzes certain features of that image through different techniques, or a combination of techniques. Finally, verifying that person's identity is accomplished by matching those features to other images stored in a database. The analysis process over the years has moved away from using a simple geometry of key facial points to the use of more complex mathematical techniques.

The four main biometric face recognition methods that are currently being used are eigenfaces, feature analysis, neural network and automatic face processing. Eigenfaces is a tool developed by MIT that extracts characteristics through the use of a two-dimensional gray-scale imagery. Feature analysis or sometimes referred to as Local Feature Analysis (LFA), is the most widely used technique because of its ability to accommodate for facial changes and aspect. LFA uses an algorithm to create a face print (84 bytes in size) for comparison. Neural network is a method that extracts features from the face and creates a template of contrasting elements that is then matched to a template in a database. Some researchers think that the neural network technology is the next step in face recognition. Automatic Face Processing (AFP) is a technique that looks for distances and distance ratios between certain facial features. But all these

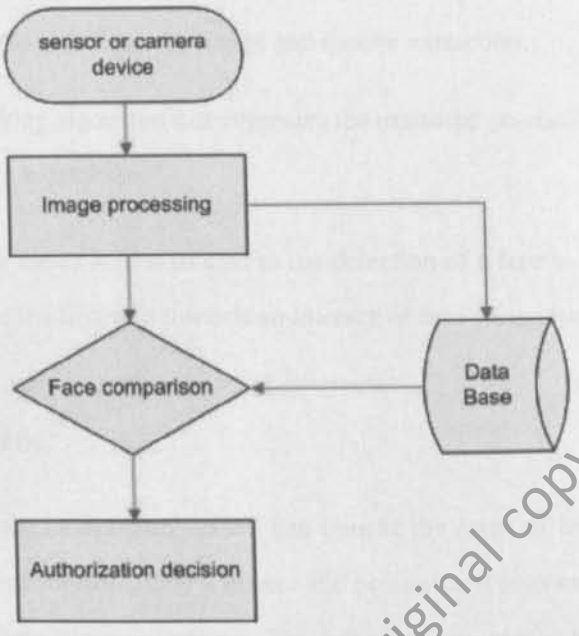

Figure 1.1: Biometric identification based on face recognition.

methods require the face to be separated from the rest of the captured image. This process is called face detection and forms the basis of this research work.

1.2 Scope

Face detection plays an important role in today's world. They have many real world applications like human-computer interface, surveillance, authentication and video indexing. However research in this field is still young. Face recognition depends heavily on the particular choice of features used by the classifier. One usually starts with a given set of features and then attempts to derive an optimal subset (under some criteria) of features leading to a high classification performance with the expectation that a similar performance can also be attained on future trials using novel (unseen) test data.

Face recognition can be divided into several phases. It includes,

- Creating drivers for the device that link the application with the captured image.

- Image processing based on several techniques including face detection algorithm which detects the face from the image and feature extraction.

- A decision making algorithm that compares the extracted geometric features with existing ones in a database.

The scope of this thesis is thus limited to the detection of a face in an image. This will help to complete the first step towards an interactive face recognition system.

1.3 Motivation

An interactive face recognition system can benefit the areas of law enforcement, airport security, access control, driver's license and passports, Homeland Defense, Customs and Immigration and scene analysis. The following paragraphs briefly describes each of these areas.

- Law Enforcement - Today's law enforcement agencies are looking for innovative technologies to help them stay one step ahead of the world's ever-advancing terrorists. Biometric identification can help the effect.

- Airport Security - The interactive face recognition system can enhance security efforts already underway at most airports and other major transportation hubs (seaports, train stations, etc.). This includes the identification of known individual persons before they get onto an airplane or into a secure location.

- Access Control - Biometric identification can enhance security efforts considerably. Biometric identification ensures that a person is who they claim to be, eliminating any worry of someone using illicitly obtained keys or access cards.

- Driver's License and Passports - A reliable identification device can leverage the existing identification infrastructure. This includes, using existing photo databases and the existing enrollment technology (e.g. cameras and capture stations) and integrating with terrorist watch lists, including regional, national and international most wanted databases.

- Homeland Defense - The interactive face recognition device can help in the war on terrorism, enhancing security efforts. This includes scanning passengers at ports of entry integrating with CCTV cameras for out-of-the-ordinary surveillance of buildings and facilities and more.

- Customs and Immigration - New laws require advanced submission of passenger from planes and ships arriving from abroad; this should enable the system to assist in identification of individuals who should, and should not be there.

- Scene Analysis - This can be defined as the act of examining images for the purpose of identifying objects and judging their significance; by studying the remotely sensed data and attempting through logical process in detecting, identifying, classifying, measuring and evaluating the significance of physical and cultural objects, their patterns and spatial relationship.

It is clear that an interactive face recognition device is essential for various security reasons. Its development can be used as a test-bed for embedded face recognition research. As such, it contributes toward building a general infrastructure for research into embedded vision, further benefiting society.

1.4 Problem Statement

The applications and the difficulty of face detection makes it an interesting problem. In terms of applications, face detection is quite important for face recognition. Hence, it becomes the most important step for a biometric identification system. So far, researchers have focused on the face recognition problem in which the task of automatically finding faces in an arbitrary background is usually avoided by either manual segmentation of the input image, or by capturing faces against a known uniform background. Face detection also has potential applications in human computer interface and surveillance systems.

Face detection is difficult due to three main reasons. First, there is a large component of non-rigidity and textural differences among faces. Facial appearance differs from face to face. Second, face detection is also made difficult because of additional features, such as glasses or a moustache, which can either be present or totally absent from a face. All these additional features increase the variability of face patterns that a face detection system should handle. Third, the presence of unpredictable imaging conditions in an unconstrained environment increases the difficulty of the task. A change in light source distribution can cause a significant change in the appearance of the face image. All these things should be taken into consideration when designing a face detection system.

Face detection is a critical first step in any automatic biometric identification system. Although research on face recognition started very early, there was not much attention to the face detection problem until recently, especially for face images with cluttered background. Over the last ten years, more attention has been given to the face detection problem and there is a large increase in the number and variety of methods attributed to face detection.

The goal of this thesis is to present an alternative method to increase the efficiency of face detection with high accuracy and high frame rate in a 2D color image of a real-time biometric identification system.

1.5 Objective

The research objective can be itemized as follows,

- Investigate current background subtraction techniques to understand the limitations of these methods.
- Explore a new technique for face detection to be used in a biometric identification system.
- Study camera sensor behavior to identify all information that can be used in the development of the algorithm.
- Formulate the proposed algorithm in a suitable format to run in real time.
- Use a high level programming language to test, validate and benchmark the performance of the proposed algorithm.

1.6 Research Methodology

In this section, a general methodology adopted in this research is provided. Details of the approaches are given in chapters 3, 4 and 5. The motivation in developing a new background subtraction algorithm is to overcome the problems and the disadvantages of the existing algorithms. The new approach also leads to many image processing applications such as shape detection. In general, this research can be divided into three stages.

In the first stage, the theoretical analysis has been done to the biometric face detection techniques in the existing applications; all the mathematical relations in the algorithms and their performance are developed and discussed.

In the second stage, after the completion of all the mathematical models, an application has been implemented to study the performance of the developed algorithm. Microsoft Visual Studio version 6.0 have been used to accomplish this work. Optimization is needed at this stage to get the best combination of codes that are suitable for applications to run in real time. The software is important since it normally considers all practical factors (although numerically), which may be too extensive to be considered in the theoretical development.

In the final stage of this research work, the experimental setup and result for the implemented algorithm is performed. Comparison between the developed algorithm and the existing algorithms are then made. The experiments were carried out in different illumination conditions in indoor and outdoor environments with dynamic and static backgrounds.

1.7 Expected Research Output

The main contribution of this thesis will be the implementation of an alternative fast background subtraction algorithm that is robust against shading and shadows for a 2D color image input video sequence. This algorithm enables the estimation of the background reference image that is accurate, robust and reliable for a biometric identification system.

The designed application will be developed using an advance scale programming language like Visual Basic Studio 6.0 to achieve accurate and fast results. This applica-

tion and its functionality will be tested and validated. The application should run under the standard Windows operating system environment on a normal PC or laptop at a very good speed. This will be the second contribution.

1.8 Thesis Outline

The organization of this thesis largely follows the order in which the work was done. The aim and objective of the thesis is presented in this chapter. Chapter 2 reviews the literature available relating to background subtraction and describe some existing applications that have been developed using some of the most popular techniques and they are critically analyzed. In addition, some performance evaluation is introduced to clarify how these methods are quantified amongst the different approaches using the most commonly used benchmarks. Chapter 3 presents the proposed algorithm to solve the problem of face detection that is crucial for biometric identification. An algorithm for the detection and localization of the face is presented in detail. Indoor and outdoor experimental results and their analysis are presented in chapter 4. The implemented system software and hardware is then presented in detailed. The performance of the algorithm is benchmarked and compared with existing applications. This report ends with the conclusion in chapter 5 together with some future directions for this work.

Chapter 2

Literature Review

2.1 Introduction

Several methods for performing background subtraction have been proposed in the recent literature. All of these methods try to effectively estimate the background model from the temporal sequence of the frames. However, there is a wide variety of techniques and both the expert and the newcomer to this area can be confused about the benefits and limitations of each method.

Research has been devoted to develop a background model that is robust against environment changes and flexible to the following dynamic situations:

- Illumination changes that is gradual or sudden.
- Motion change that are internal or external.
- Geometry change that is intentional or unintentional.

The general aim of the background subtraction algorithm is therefore to construct a model that is responsible for generating a background image and a binary mask that displays all foreground objects in the current frame. Also incorporated in some of these techniques is the detection and elimination of shadows in the scene. These techniques can handle situations where the background of the scene is cluttered and not completely