Features Extraction using Thermal Face Image Recognition

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أستخراج الخصائص بأستخدام التعرف على الصورة الحرارية للوجه

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Resolution of the Examining Committee

This dissertation, titled "Features Extraction using Thermal Face Image Recognition ", has been defended and approved on February 19$^{th.}$ 2014.

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Dedication

This thesis is dedicated to my parents for their love, endless support, blessings and encouragement, whom I always felt next to me.

To my lovely brother,

To my lovely friends, Rafal and Zayd

Acknowledgment

Praise is to Allah for the uncountable blessings and grace bestowed onto me to achieve my dream.

I would like to express my sincere appreciation and deepest gratitude to my supervisor Dr. Akram Othman Al-Mashaykhi for his guidance, suggestions, attitude, and encouragement throughout the preparation of this work.

Also, I would like to express my thanks and appreciation to the Arab Amman University for providing the opportunity to undertake my postgraduate studies leading to the M.Sc degree and to the Department of computer science for providing the support and facilities needed to complete this work.

Contents

List of Abbreviations

Abbreviations	**Meaning**
AAM	Active Appearance Model
ABIFGAR	Advanced Biometric Identification on Face, Gender and Age Recognition
ANN	Artificial Neural Networks
BRIEF	Binary Robust Independent Elementary Features
HMMs	Hidden Markov Models
ICA	Independent Component Analysis
IR	Infrared
IRIS	Imaging Robotics and Intelligent System
LBP	Local Binary Patterns
LDA	Linear Discriminant Analysis
LWIR	Long-Wave Infrared
MLP	Multilayer Perceptron
MWIR	Mid-Wave Infrared
NIR	Near Infrared
NVIE	Natural Visible and Infrared
PCA	Principal Component Analysis
PDBNN	Probabilistic Decision-Based Neural Network
PIN	Personal Identification Number

RDT-DWT	Real Dual Tree Discrete Wavelet Transform
RHT	Randomized Hough Transform
SIFTS	Scale-Invariant Feature Transforms
SOM	Self Organization Map
SURF	Speeded Up Robust Feature
SVM	Support Vector Machines
SWIR	Short-Wave Infrared
UV	Ultraviolet Radiation
VLWIR	Very Long- Wave Infrared

List of Figures

Chapter One

Chapter Two

Chapter Three

List of Tables

Abstract

Face recognition, using thermal images, has become an area of growing interest due to the increased demand of security applications in many organizations such as airports, banks …etc.

Thermal face recognition is a robust system that is employed under all lighting conditions including total darkness also if the person is wearing a disguise, fake nose or make-up.

The main problem in thermal face recognition is how to extract the features that distinguish one person from another. In this work, a model is proposed for the extraction of physiological features to identify the person based under different expressions and illuminations. The model is comprised of four logically sequential stages aimed at verifying the results then their analysis.

In the processing of this model, IRIS (Imaging Robotics and Intelligent System) database is used. First, many enhancement filters are used in the pre-processing module to enhance the images, morphological operations and noise removing filters are presented. Secondly, blob detection is employed in the detection module to detect the features blobs regions. These blobs represent the region of eyes, mouth, and nose. In the third stage of the features extraction module, a set of geometrical features such as distances, slopes, and center points between the extracted blobs are computed. In the fourth stage of the classification module, the proposed model is employed. Good results of features extraction and image classification are obtained.

The results of the proposed model during the experimental treatment of different individuals and number of images varied between 55% and 85%. From the analysis of results, the relative variation for some images is attributed to the poor quality of images used in the experimental treatment.

Finally, the thesis presents some conclusions and suggestions for future work to develop the proposed model further.

الملخص

تكتسب تقنية التعرف على الوجه باستخدام الصور الحرارية اهمية متنامية جراء تنامي احتياجات التطبيقات والاستخدامات الامنية في العديد من المؤسسات والمطارات والمصارف وغيرها، ويعتبر تمييز الوجه باستخدام الصور الحرارية من أفضل الانظمة التي تعمل تحت جميع ظروف الانارة من ضمنها العتمة التامة ،اضافة الى حالات استخدام الشخص قناعاً او انفاً صناعياً او وضع مكياج لتغيير هيئته.

إن المشكلة الاساس في تمييز الوجه هي كيفية التعرف على الصفات من شخص الى آخر. هذه الرسالة حددت مجموعة من المتطلبات الضرورية لاقتراح نموذج وتنفيذه برمجياً لاستخراج الصفات الفيزيولوجية بهدف التعرف على الشخص تحت ظروف مختلفة من تعابير الوجه والانارة وقد تضمن النموذج اربعة مراحل متسلسلة منطقياً للتحقق من من النتائج ومن ثم تحليلها. لقد تم استخدام قاعدة بيانات IRIS والمعرفة " الروبوتات المصورة والانظمة الخبيرة" للحصول على الصور الحرارية خلال مراحل تنفيذ النموذج. ففي ***المرحلة الاولى*** من التنفيذ وهي وحدة المعالجة الاولية تم استخدام عدة مرشحات لتحسين الصور كما تم استخدام مرشحات خلال العمليات المورفولوجية وإزالة التشويش. في ***المرحلة الثانية*** وهي وحدة التعرف استخدمت تقنية التعرف على مواقع البقع او العقد في الصورة وتشكل هذه البقع مواقع العين والفم والانف. أما في ***المرحلة الثالثة*** وهي وحدة استخراج الاوصاف تم حساب مجموعة من الخواص الهندسية والتي تضم المسافة والميل والنقاط المركزية بين البقع المستخلصة. أما في ***المرحلة الرابعة*** تم استخدام الاسلوب المقترح في هذا البحث والذي من خلاله تم الحصول على نتائج جيدة في مجال الاوصاف والاداء في التصنيف حيث تراوحت النتائج للاشخاص و اعداد نماذج الصور خلال المعالجة التجريبية للنموذج المقترح بين 55% و 85% بالمائة وان تحليل النتائج قد عزى نسبة التفاوت النسبي في بعض الحالات الى تدني درجة وضوح بعض الصورالمستخدمة في المعالجة التجريبية. وتنتهي الرسالة الى تقديم بعض الاستنتاجات والمقترحات للعمل المستقبلي لتطوير النموذج المقترح.

Chapter One

Introduction

Chapter One
Introduction

1.1Overview:

In recent years, the world has witnessed global population growth explosion in addition to an increasing demand for mobility by the modern society. Such situation demanded development of a variety of identity management systems, especially in security establishments, particularly those involved in efficient recording and maintaining safe identities of personnel. The required systems need to safeguard against manipulation or destroying information. Several systems have been developed, but some proved prone to deliberate attacks (Yang, J. and Poh, N. 2011).

Identification management systems are important to many secure information applications. Traditional approaches served the purpose adequately, but with the advent of computers and their introduction to find new approaches were considered necessary. Such needs were the impetus to computer science experts to unleash their innovations to counteract such hazards. Recent research efforts have been tremendous all over the world. It appears there are still some shortcomings that require further mobilization of efforts with the increasing intrusions of records that can obliterate and manipulate vitally important information. All are convinced that more developments have to be made. Newly emerging and promising techniques are biometrics characteristics that can be used in identity management, in view of their immense competence (Yang, J. and Nanni, L. 2011).

In identity management system, a highly vital role is establishing an associative relation between a person and relevant personal identity. Such role is the ability of determining the individual's identity on the one side, and verification of an identity claim of a person on the other side, whenever the need arises as required by the system. Such process is designated and known as person recognition. The recognition of a person is performed on the basis of three fundamental methods (El-Abed, M. et al. 2012):

(a) The knowledge the person possesses;
(b) Prominent external characteristics and features;
(c) What the person's intrinsic individuality is?

The first method is dependent on the fact that the individual is in possession of exclusive knowledge of some classified information, that include passwords, identity personal, as is known as ID that incorporates passwords or other cryptographic key.

The second method involves the person in possession of different vouchers, such as driving license, identification card, passport, physical key, or personal device such as a mobile phone.

The third method employs recognition of prominent physical traits, color of eye, and finger or palm print. This is method is generally known as biometric recognition. It may be defined as scientific investigation of establishing the person's identity via the physical or behavioral characteristics of the person.

Biometric types require the provision of seven highly important factors that include the following (El-Abed, M. et al. 2012; Jain, A. K et al. 2008):

1. **Universality**: The same characteristics to be measured must be sought in all individuals;
2. **Uniqueness**: Same identical biometric features are never possessed by different individuals;
3. **Permanence**: The individuals characteristics must not change with time;
4. **Measurability:** The characteristics avail themselves to measurement in order to extract vital information sets;
5. **Performance:** The recognition accuracy of the measuring or identifying devices must be accurate with very good resolution and precision for the identification or recognition of the biometric data.
6. **Acceptability:** The individuals that undergo recognition should not feel their privacy and human rights are violated by the intervening biometric system;
7. **Circumvention:** This involves the degree of ease of tricking the biometric system.

Biometrics present themselves the owners of several advantages over traditional knowledge-based authentication systems; these advantages include (El-Abed, M. et al. 2012; Jain, A. K et al. 2008):

1. Deters fraudulent attempts and improves security;
2. Recognizes duplication and multiple records and enrollments;
3. It is difficult to be transferred, forgotten, lost or copied;
4. It eliminates disclaimer claims;
5. It provides increased user convenience.

At the present times, security has become of great priority in the field of distinguishing one person from another; this may be accomplished by iris, finger-print, voice or any other physiology-based biometrics methods. Among these face recognition methods have emerged as one of vitally important types of biometric techniques to identify or recognize the person's face features.

The features for each and every person are unique, which render themselves available to be used to construct robust face recognition systems for increased reliability. Face images are of multi-importance; they can be used for human recognition in addition to other attributes including such attributes as age, gender, and skin complexion and face expression. Such system is used in a variety of applications, such as security system, ID validity, military, missing person and others (Kong, S. G. et al. 2005).

Face recognition system generally consists of five stages (Kshirsagar, V. P. et al. 2011), as illustrated in figure (1.1):

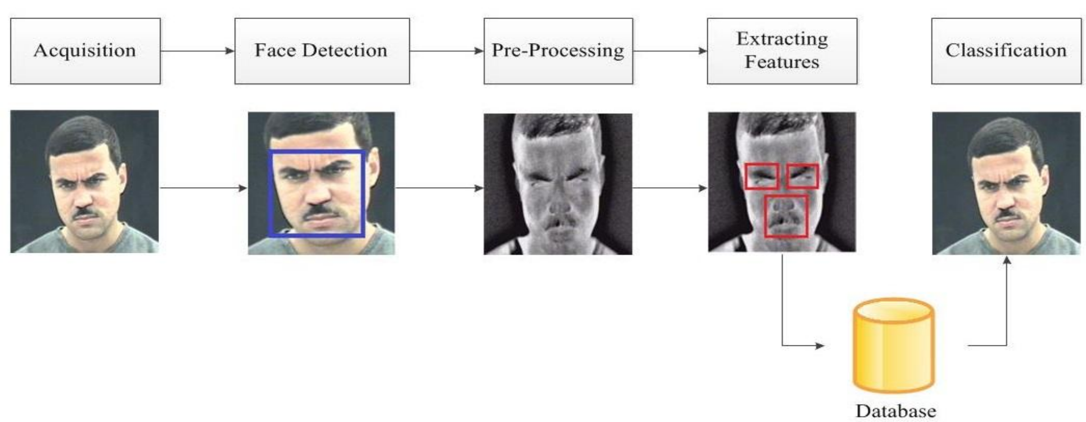


Figure (1.1): Generic Face Recognition System

First Stage: Acquisition, this is the entry point to the system. The input can be visual image, infrared image or video.

Second Stage: Face detection, to detect the face from the background;

Third Stage: Pre-processing, to enhance the images for improving the recognition system;

Fourth Stage: Extracting Features, to find the key features that will be used for classification and those features will be a combination of global and grid features.

Fifth Stage: Classification, to classify the extracted features of the face images and compared with the ones stored in the face database.

Extracting features is a very important module in any face recognition systems because the algorithms aim to find features from the scenes to identify one face from another and play an important role in many applications like face detection, expression recognition, face recognition and head pose. Extracting features techniques are based on two methods (Sharif, M. et al. 2012):

1. **Analytic or Feature-based Methods**: computes a set of geometrical features from the face like the eyes, mouth, eyebrows, and nose. The features can be properties and relation like distances, areas and angles between the features points used as information for face recognition.
2. **Holistic or Appearance-based Methods:** represent the global properties of the human face structure.

These methods are very sensitive to many non-ideal problems such as noise, time consuming, and orientation. But also the good feature extraction will increase the performance and accuracy for the face recognition system

.

In general, face recognition utilizes two types: visible and thermal images. Face recognition, employing thermal infrared images, has become more interesting and proved more useful than face recognition employing visible images, when attempting to identify or verify one or more persons. The latter technique encounters several difficulties under uncontrolled environments, such as indoor and outdoor lighting conditions. Other factors include variation in aging, low lighting, disguise, and others. Based on the fore-mentioned advantages of thermal infrared systems, it has become the focus of growing global research interest (Corcoran P. M. 2011).

Thermal infrared image recognition is not restricted by lighting conditions, i.e it is independent of lighting conditions. Infrared (IR) of different IR energy is emitted by hot objects in accordance with their temperature and characteristics, therefore, thermal IR images is a representation of the heat pattern emitted by the face of the person under investigation. The face thermal images are derived from the pattern of superficial blood vessels under the face skin. Different individuals have different vein and tissue structure of the face, making these unique for each person, thus, IR thermal face images are unique. Different lighting conditions, dark or varying intensity lightings do not constitute a limitation. In addition, since IR radiation is emitted due to face temperature, and then it is fail-proof, in cases if a person wears a face disguise, such as mask, artificial nose, and different type of cosmetic makeup (Corcoran P. M. 2011; Kong, S. G. et al. 2005).

1.2 The Statement of Problem:

The impetus to undertake such research problem is motivated by the importance of the identification problem especially in our world because the security has become of great priority in the field of identifying one person from another. The most common person identification and verification methods today such as password, Personal Identification Number (PIN), driver's license and so on. These methods have some problems with fraud, theft and threats from hackers. Because of that, it has developed a significant interest in biometric identification systems, which use face recognition to identify people.

Face recognition systems based on thermal imagery represent a good research area for a robust and practical identification system compared to visible images.

This study focuses on extracting the facial thermal features from the infrared images by detection the important points that are useful to compute a set of geometrical features that are used for identification during the process. The classification process will use face images during different expressions, poses and illumination for each person. The features can be distances, angles or areas that are related to the eyes, mouth and nose.

1.3 Methodology, Modules and Operational Structure of the Proposed Model:

In this study, the proposed thermal face recognition model is divided into five main modules and each module consists of several steps. The block diagram of the proposed model is shown in figure (1.2). The modules are listed as follows:

1. Acquisition Module (replaced by IRIS Thermal/Visual Database).
2. Pre-processing Module.
3. Detection Module.
4. Features Extraction Module.
5. Classification Module.

During the processing of this model, the second module, which is the pre-processing module will try to enhance the thermal images to be more useful than those from the source. Many filters, including morphological operations and noise removing filters will be applied. The third module, which is the detection module will use blob detection to detect the features blobs regions.

The fourth module is the features extraction. It will use feature-based methods to extract features that are a set of geometrical features such as distances, slopes and center points. The fifth module is the classification module, in which an approach is proposed in this study to explore for the matching between two persons, based on different expressions and illuminations of the same person.

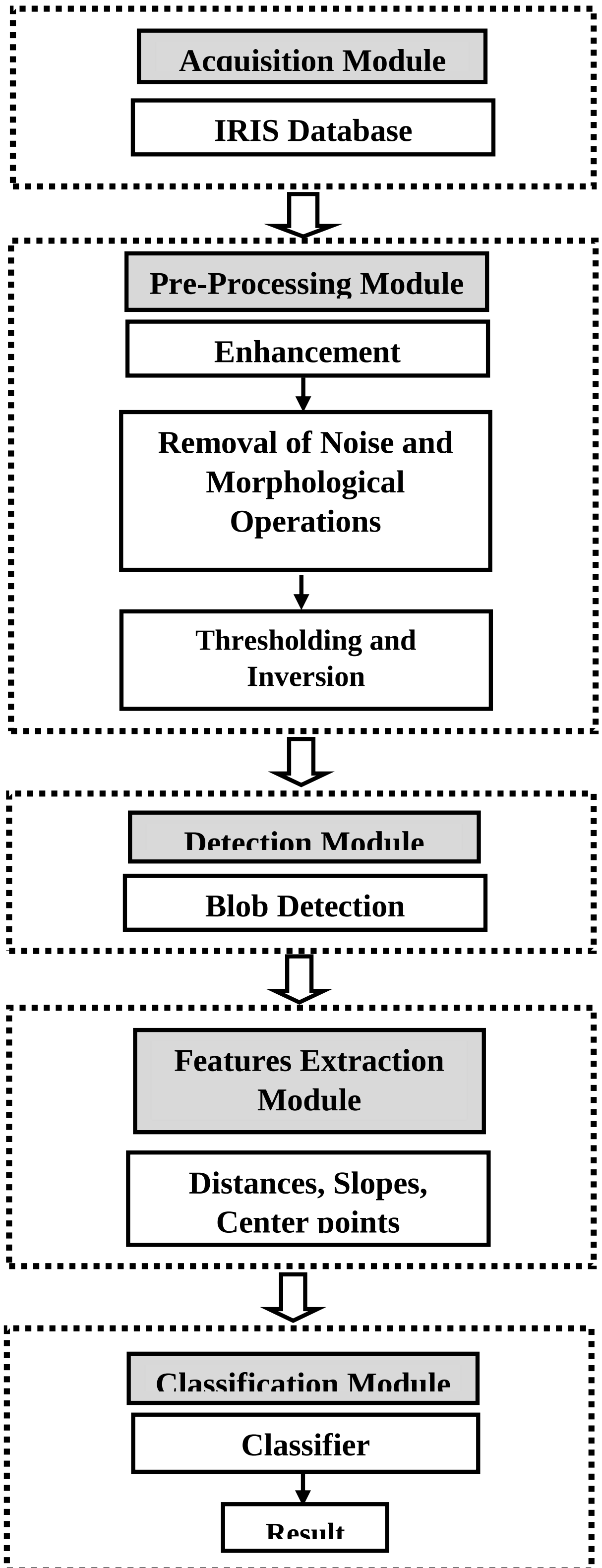


Figure (1.2): Block Diagram of the Proposed Model

1.4 Objectives of the Study:

In any study that is related to the face recognition fields, the main goal or objective is achieving high rate of recognition. In other words, classifying or features extraction accurately.

The objective of this study was to develop a reliable thermal facial recognition model that identifies a person objects under a variety of conditions, illuminations, and expressions. This thesis aims at providing solutions to existing challenges and limitations in facial recognition, and to improve the effective application of facial recognition technology as security surveillance in various public places, while the main objective is to evaluate the features extraction techniques that uses in this study.

1.5 Contribution:

The goal of the present thermal face recognition study is to contribute in the advancement of face recognition technology, designed to supplement existing face recognition efforts undertaken by other researchers. It is hoped this study will be an attempt to develop further models while increasing performance by an appreciable degree of magnitude.

A significant number of algorithms and advanced methods for implementing thermal face recognition are declared in pattern recognition literature. However, some efforts have been expended on extracting and classifying the bio-physiological. This study focuses on developing effective computation of thermal feature extraction that uses a set of geometrical features and for classification module; it presents an approach that is employed in this study.

1.6 Thesis Overview and Organization:

This thesis is comprised of four chapters, including the present chapter and a list of references.

Chapter Two presents several studies and research papers that are related to this study. Moreover, it discusses the face recognition system in general and explains each module, acquisition module, face detection module with the most common methods, pre-processing module, extracting features module with some types of methods and classification module. Furthermore, it discusses thermal face recognition with its advantages and the drawbacks, infrared spectrum and the types of databases for face recognition. At the end of this chapter, some published research papers and literature review relevant to this study are presented.

Chapter Three presents the proposed model for this study that contains five modules to solve the proposed problem, explanation of each module, selection of the suitable techniques, gives the details related to the algorithms with sample results for the thermal face images after each module process.

Chapter Four provides a summary of the proposed model, discusses the results and presents some suggestions for future work to develop the approach presented in this thesis.

References section is appended at the end of this thesis. It provides a list of cited work.

Chapter Two

Literature Study

Chapter Two

Literature Study

2.1 Overview:

The security has become a very high priority especially in the field of identification problems to distinguish one person from another. This situation has prompted many researchers to develop the uniqueness of each and every person to build robust recognition system that should be more reliable.

This thesis focuses on thermal face recognition. This chapter presents several studies and research papers related to the subject under study; moreover the chapter discusses the face recognition system in general and explains each module, such as acquisition module, face detection module with the most common methods, pre-processing module, extracting features module with some types of methods and classification module.

Furthermore, it discusses thermal face recognition with its advantages and drawbacks, infrared spectrum, and types of databases for face recognition.

At the end of this chapter, some published research papers and literature review relevant to this work presents.

2.2 Design of Face Recognition System:

Face recognition system consists of five modules to recognize the human faces and classify the face whether it is known or unknown, as shown in figure (2.1). The system consists of many functions and duties as-signed to each module (Kshirsagar, V. P. et al. 2011).

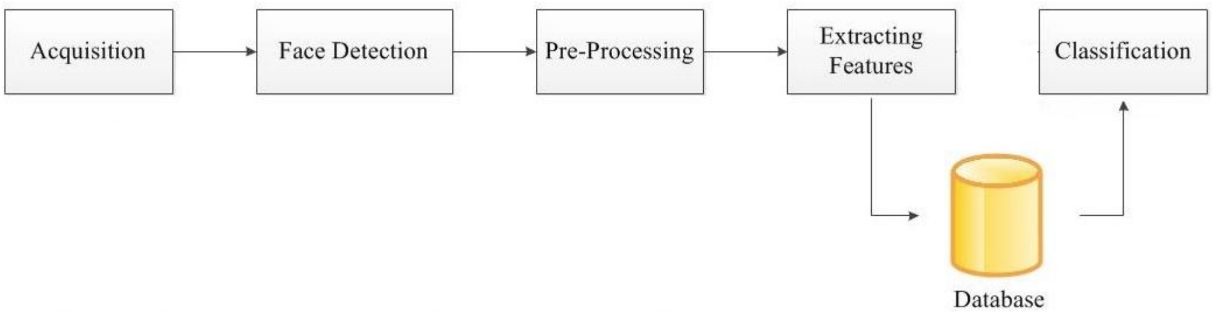


Figure (2.1): Face Recognition System

2.2.1. Face Acquisition Module:

This is the entry point to the system. The three major types of image format are 2D, 3D and videos. There are two types of technique in acquiring the images: visual and thermal imaging. Visual images, acquired by optical cameras, are more common than thermal images acquired by infrared cameras in view of the availability and the low cost of visible band optical cameras. But on the other hand, optical cameras need an external source of illumination.

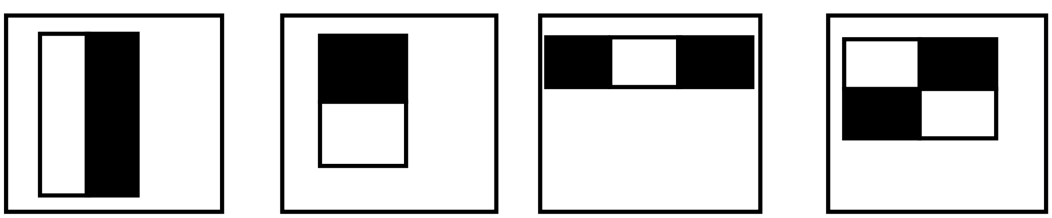
Recently, many researchers have focused on thermal infrared imagery and noticed better accuracy and good results can be acquired because it is independent of ambient lighting conditions and the Infrared (IR) sensors acquire the heat pattern emitted by the object. A facial thermal pattern is determined by the emission of IR from the superficial blood vessels under the skin (Jain, A. K. et al. 2011).

2.2.2. Face Detection Module:

There are many techniques employed for detecting faces in a given image. State of the art of face detection methods are based on extracting local texture features from image to distinguish between face and non face features. There are many important and common types of face detection methods, such as Viola-Jones face detector and Haar like features (Zhang, C., and Zhang, Z. 2010).

2.2.2.1 Viola and Jones Detector:

The use of this detector has become very common method especially for face detection and widely used because of its real time capability, availability and high accuracy detection rates. Viola and Jones face detector scans through the input image with a detecting window; doesn't matter if each widow contains face or not. The presence of a face is decided by applying a classifier derived by using a multi-rectangle feature system filters to locate features and edges of the face; these features are identified by passing a threshold belonging to a face (Viola, P., and Jones, M. 2001, 2004). These rectangle filters are grouped into two, three and four rectangle filters as shown in figure (2.2).



(a) (b) (c) (d)

Figure (2.2): (a) and (b) two rectangle filters, (c) three rectangle filters, (d) four rectangle filter.

There are three main contributions in Viola-Jones face detector framework; first contribution is called an integral image to represent the structure of the image and the features are calculated by taking the sum of pixels of multiple rectangle areas. Second contribution is to build by selecting the small number of important features from a big library of possible features using Adaboost to ensure fast classification. The third contribution is to use cascading classifiers to speed the system up.

The Viola-Jones detector uses and combines different types of filters such as Haar-like filter for face detection. When the combination of filter responses or features in a certain window passes the threshold then the face is said to have been detected. The feature values are obtained by computing the difference between the sum of pixel intensities in the light and dark rectangular regions (Viola, P., and Jones, M. 2001, 2004).

Even though the Viola-Jones face detector has an excellent performance in real time applications but it still has some problems (Jain, A. K. et al. 2011):

1. The detector is not perfect and can produce false positive error which refers to the detection of a face when none exists and false negative error which indicates that a face in the image was not detected.
2. The detector struggles with non-frontal facial poses, occlusion, and changes in illumination and so on.

2.2.3. Pre-processing Module:

In this module, many processes are applied to enhance and improve the recognition of the system. Some methods of image processing include several processes such as: cutting, filtering, normalization, histogram equalization, smoothing, background removal, and morphology operation, contrast and so on. The preprocessing operations are very important for improving the quality of the images (Kshirsagar, V. P. et al. 2011).

2.2.4 Extracting Features Module:

The face image serves as input to this module. Extracting features module is the core of the face recognition system and provides effective information that is useful to distinguish one face from another. Most feature extraction methods are sensitive to various non-idealities such as noise, time consuming orientation and so on. The good methods will increase performance and accuracy of face recognition system.

There are many different types of face recognition methods, these methods can be classified into two groups: analytic or feature-based methods and holistic or appearance-based methods. Some of these methods are used for extracting features and classification (Kong, S. G., et al. 2005; Keche, J. K. and Dhore, M. P. 2012).

2.2.4.1 Analytic or Feature-based Methods:

The feature-based methods compute a set of geometrical features from the face such as nose, eyes and mouth. The descriptors for face recognition in these methods are the properties and relations such as areas, distance and angles between the feature points. There are many types of feature-based methods especially used for thermal images, such as Gabor wavelet transform, local binary patterns (LBP), vascular network and blood perfusion and others (Keche, J. K. and Dhore, M. P. 2012).

2.2.4.2 Holistic or Appearance-based Methods:

The appearance-based methods are based on the global properties of the human face pattern. The face is recognized as whole without using fiducial points. In these methods, linear transformation and statistical data are used to find the basic vectors that represent the face. These methods advance by projection of an image into the subspace and finding the closet point (Kong, S. G., et al. 2005; Hermosilla, G. 2012).

The most common appearance-based methods used in face recognition for dimensionality reduction and feature extraction are Principal Component Analysis (PCA) and Linear Discriminant Analysis (LDA).

- **Eigenface or Principal Component Analysis (PCA):**

For the process of face recognition, the Eigenface or Principal Components Analysis, (PCA) is the most popular method for global features extraction; it was proposed by Turk and Pentland (Turk, M. A., and Pentland, A. P. 1991).

In face recognition domain, there are several features present in the face, such as eyes, nose and mouth, besides relative distances between the fore-mentioned features, which are in turn called eigenface. The eigenface constitute the principal components of the initial training set of face images. In order to perform recognition, a new image is projected onto the subspace spanned by the eigenface (face space), followed by face classification with regard to its position in the face space relative to position of known individuals. A vital task is to find the eigenvectors of the covariance matrix of the set of face images, also known as the principal components of the distribution of faces; these eigenvectors can be thought of as set of features, which together characterize the variation between face images. Individual images contribute more or less to each eigenvector, so that eigenvectors can be displayed as a type of ghostly face, known also as eigenface (Turk, M. A., and Pentland, A. P. 1991; Hermosilla, G. 2012).

- **Fisherface or Linear Discriminant Analysis (LDA):**

The traditional linear discriminent analysis (LDA) is known as Fisher's discriminent analysis. This method is a very common method in pattern recognition projects, used for dimensions' reduction. Its application involves the projection of the original high dimensional data onto a low-dimensional space, and as a result creates a linear combination of independent features, yielding the largest mean dimensions between the desired classes.

In recent years, many LDA methods have been proposed in order to solve the linear discriminent in the small sample size problem. The highly popular method is called the Fisher faces, which combines PCA and LDA for dimensionality reduction in order to make the within-class matrix nonsingular, but with loss of some useful discriminatory information (Jain, A. K., et al. 2008).

- **Independent Component Analysis (ICA):**

The aim of the Independent Component Analysis (ICA) is the transformation of the data as a combination of statistically independent data points to provide an independent rather than uncorrelated image representation.

The ICA method can be considered as an alternative to PCA, which offers more powerful data representation. ICA can be used to enhance PCA, since it is a discriminent analysis criterion (Jain, A. K., et al. 2008).

- **Artificial Neural Networks:**

Artificial Neural Networks (ANN) techniques have been widely used in the field of face recognition. ANN techniques are used for feature representation, data reduction, data compression and classification. ANN is an adaptive system that changes the information during the learning phase based on internal or external information that flows through the network.

There are many different methods based on neural networks, just for classification or for finding features. The most popular and robust methods are: Self Organization Map (SOM), Multilayer Perceptron (MLP), Probabilistic Decision-based Neural Network (PDBNN), Hidden Markov Models (HMMs)... etc (Kong, S. G., et al. 2005).

2.2.5 The Classification Module:

The extracted features of face image are compared with the ones stored in the face database or directory files. The face image is then classified as either known or unknown. In the database, if the face is recognized as “unknown”, face images can then be added to the database for further comparisons. There are many types of classification techniques such as (ANN techniques, PCA, LDA and so on). Some of these techniques are used for extracted features and classification at the same time (Kshirsagar, V. P. et al. 2011).

2.3 Thermal Face Recognition:

Face recognition using infrared (IR) imaging sensors has become an area of growing interest. Electromagnetic spectral bands having wavelengths lower than those of visible spectrum, such as ultraviolet radiation (UV) and X-rays are harmful to the human body and cannot be utilized for face recognition. Thermal IR images represent the heat patterns emitted by an object. Objects emit different amounts of IR energy depending on their temperature and characteristics. The range of human face and body temperature varies from 35.5 to 37.5°C that provide regular thermal signature. The source of the IR patterns of thermal faces is the pattern of superficial blood vessels under the skin. Warm blood is transported throughout the body. IR images are considered unique since the vein and tissue of the face structure is unique for each person (Corcoran, P. M., 2011; Jain, A. K., et al. 2011).

The advantages of using thermal IR imaging over visible spectrum sensors include the following (Corcoran, P. M., 2011; Jain, A. K., 2011; Kong, S. G., et al. 2005):

1. Thermal image is not vulnerable to disguises since it cannot be altered or camouflaged.
2. The radiation within the thermal IR range is emitted rather than reflected. Thermal emissions from skin are an essential property, independent of illumination. The face images captured by thermal IR sensors will not be significantly changed under varying ambient illumination. IR energy is not affected by scattering and absorption by smoke or dust as compared with visible light.

3. Thermal face detection of disguised faces can be performed under various lighting conditions including total darkness. Two types of disguises exist for altering facial characteristics: artificial materials (makeup, fake nose or wig) and surgical alterations (modification of facial appearances through plastic surgery). Plastic surgery may alter skin tissue size i.e. add or reduce, redistribute fat, add silicon, and create or remove scars. Alterations of blood vessel flow may be caused by such surgical operations, however, in effect may appear as distinct cold spots in the thermal imagery.
4. It can be used as an effective diagnostic tool of skin temperature distribution for breast cancer detection, target detection in military applications and heat source recognition for inspection of electronic parts.

Although thermal images are very useful in accurate face recognition but they suffer from some drawbacks or limitations when considering the following (Corcoran, P. M., 2011):

1. Identical twins.
2. During exhale-inhale, the skin temperature is altered.
3. Some metabolism effect; symptoms such as alertness and anxiety are difficult to hide due to the redistribution of blood flow in blood vessels which causes unexpected changes in local skin temperature.
4. Effects of glasses use.

5. Energetic physical activity, consumption of food, alcohol, and caffeine and other activities may also influence the thermal characteristics.
6. Thermal images have low resolution.
7. Thermal cameras are very expensive.

2.3.1 Infrared:

Infra means below in Latin and the name Infrared means below red. Red is the color of the longest wavelengths of visible spectrum. Infrared light has a longer wavelength and a lower frequency than that of red light; it is not visible to humans as a result of which came the meaning of below red. Infrared (IR) light is electromagnetic radiation with a wavelength between 0.7 and 300 micrometers (Corcoran, P. M., 2011; Akhloufi, M., 2008).

2.3.2. Infrared Spectrum:

Objects generally emit infrared radiation across a spectrum of wavelengths, but only a specific region of the spectrum is of interest to any application, because sensors are usually designed only to collect radiation within a specific bandwidth (Corcoran, P. M., 2011; Akhloufi, M., 2008). The IR spectrum extends over a wavelength range, and each band is assigned different names according to nature of its field of application, as shown next:

1. **Near Infrared (NIR):** range from 0.74 - 1 µm, used in telecommunications.
2. **Short-wave Infrared (SWIR):** range from 1 - 3µm, used in remote sensing.
3. **Mid-wave Infrared (MWIR):** range from 3 - 5µm, used in high temperature inspection (indoors, scientific research).

4. **Long-wave Infrared (LWIR):** range from 8 - 14µm, used in ambient temperature inspection (outdoors, industrial inspection).
5. **Very Long- wave Infrared (VLWIR):** range from 14 - 1000µm, used in spectrometry and astronomy.

The useful infrared, employed in thermal imaging, extends over three spectral ranges; each range is employed depending on the face and surrounding temperature as appear below:

1. Short-wave Infrared (SWIR)
2. Mid-wave Infrared (MWIR)
3. Long-wave Infrared (LWIR)

The best spectrum used in face recognition is the LWIR because the emission is much higher than that in the MWIR.

2.4 Databases for Face Recognition:

Face Recognition is the most popular research area of computer vision and machine learning. Along with the development of face recognition techniques, very large number of face databases has been collected. Most of these databases are publicly available to any researcher. Some of these databases contain visible images or only thermal images or both. Each database has many properties such as (facial expressions, illumination, pose, gender, different disguises, and sizes of the database and of each image, image format, and so on) (Li, S. Z., and Jain, A. K. 2004).

2.5 Literature Review:

The literature review presented here is brief in that it focuses only on aspects relevant to the research problem in this study such as; the objective, environment and boundary, context, and methodology. In addition, the main contributions of each of several recent, yet important research papers are presented in this part of the thesis:

Trujillo, L., et al. (2005). "Automatic Feature Localization in Thermal Images for Facial Expression Recognition".

In this work, an unsupervised local and global feature extraction system is proposed based on facial expression recognition in thermal images. The proposed system is divided into three stages. First stage: facial feature localization was applied based on the property that the higher image intensities correspond to regions with higher thermal content. In order to locate the face center via computing the geometric centroid, the bi-model thresholding technique is applied over the entire image frame. Harris operator is used for point of interest detection location of the facial features. The next step, the K-means clustering with Euclidean distance measure minimization is applied to extract facial regions. Second stage: it involves computing representative Eigen-features for each facial region that is extracted, by using the Eigen-images based on Principal Component Analysis (PCA). Third stage: in this stage, facial expression classification is applied by using Support Vector Machines (SVM). During this stage, SVM is trained to be able to classify the images in the dataset. Different SVM's are trained for each image region.

The experimental result was achieved with good feature localization and classification performance.

Mazurkiewicz, J., and Bauer, J. (2005). "Thermal Imagery-Based Recognition Used Neural Networks and Joint Transform Correlator".

This paper involved performing and focusing on implementation of infrared-based biometric system using neural networks. Two types of neural network techniques are used: multilayer Perceptron and Kohonen networks; the results of the classification and identification of human face thermograms, obtained through classification using Kohonen neural were about 75% and identification for Kohonen neural about 86%. The results of the classification and identification of human face thermograms, realized by artificial neural network, are discussed, based on different sizes and topologies of the Kohonen layer as well as being based on different methods of neurons distance calculation applied during teaching process.
The problem of the low stability of thermal pattern was also tested; the results appeared to be very promising. In general, no significant influence was observed on the results by the number of epochs used during the training process as well as kind of topology (grid or hexagonal).

Abas, K. H., and Ono, O. (2009). "Implementation of Frontal Centroid Moment Invariants in Thermal Based Face Identification System".

This paper involved proposing thermal-based face identification system and presented the implementation of moment invariants and centroid point as obtained from frontal images. For background filtering, Seeded region growing was applied. The system decomposes background filtered thermal images into 4 thermal regions employing 3-valued threshold method to discard the lowest valued region (coldest region) from the processes. The centroid point is computed from the holistic frontal view and registered prior to computation of the moment invariant (or moment inertia) for each decomposed thermal region. The system employs minimum distance measurement method for classification.

The performance of this system was 92.5 % for correct identification rate for testing registered image ratio of 2:1 and 90% of correct identification rate for testing registered image ratio of 4:1.

Ramesha, K., et al., (2009). "Advanced Biometric Identification on Face, Gender, and Age Recognition".

This paper deals with a proposed robust algorithm called Advanced Biometric Identification on Face, Gender and Age Recognition (ABIFGAR). The face recognition system realized good accuracy in personal identification when it is provided with a large number of training sets. In this algorithm, good results are obtained when only small training set is available and it works as well with a training set as small as one image per person.

The face images are pre-processed using color conversion, noise reduction and edge detection method (Canny edge detector is used to derive the edges of face images). Global and grid features' combination is used during the feature extraction stage. The gender is classified using the posteriori class probability classifier and the Artificial Neural Network, used to classify age based on features of face images.

The ratio for face matching was 100%, gender classification 95% and the age classification was 90%.

Arandjelovic, O., et al., (2010). "Thermal and Reflectance based Personal Identification Methodology under Variable Illumination".

The paper aimed at authenticating persons based on the appearance of their faces. This is considered as a very difficult pattern recognition problem in view of the fact that facial appearance is generally greatly affected by the changes in the way a face is illuminated, by the camera viewpoint and partial occlusions. A fully automatic algorithm is described that systematically addresses each of these challenges for personal identification based on two types of images, one acquired in the visible region and one acquired in infrared electromagnetic spectrum; it means fusion system to provide good illumination invariance and discriminative power between individuals. The effects of preprocessing of data in each domain are examined, the fusion of holistic and local facial appearance, in an attempt to propose an algorithm for combining the similarity scores in visual and thermal spectra in the presence of prescription glasses and significant pose variations, using a small number of training images (5–7).

The proposed method has proved the ability to achieve high correct identification rate of 97% by using data set containing extreme illumination changes and a small number of training images.

Seal, A., et al., (2011). "Minutiae Based Thermal Face Recognition Using Blood Perfusion Data".

An efficient approach for face recognition is described based on blood perfusion data from thermal face images and on the temperature variation across the face, which can be easily visualized as different color regions in the thermogram. Blood perfusion data are related to distribution of the blood vessels under the face skin and do not depend entirely on surrounding temperature. A distribution of blood vessels are unique for each person and as a set of extracted minutiae points from a blood perfusion data of a human face should be unique for that face. The entire face image is divided into equal number of blocks and the total number of minutiae points from each block is considered as one feature and those features from all blocks are combined to create the final feature vector. Therefore, the size of the feature vectors was found to be same as total number of blocks considered. The classification of those feature vectors has been performed using a five layer feed-forward back-propagation neural network.

The recognition rate has been enhanced by varying size of blocks, performance rate for (8×8) block was 91.47%, (16×16) block was 69.44% and (32×32) block was 83.33%.

Gaweda, A., and Patterson E., (2011). "Individual Identification Based on Facial Dynamics during Expressions using Active-Appearance-based Hidden Markov Models".

In this work, a robust method is presented to quantify the physical features of individual identification, based on facial dynamics during expressions through similarity. Throughout this method, Stacked Active Shape Models for automated face detection and labeling was applied; Active Appearance Model (AAM) is used for feature extraction, and Hidden Markov Models used for data analysis. AAM parameters used with HMM classification proved to be effective, and the number of states for each HMM is tested for an optimal setup in each experiment. Static, combined, and dynamic-only parameters are tested together with dynamic parameters producing recognition rates comparable to other techniques.

The aim of this model was to demonstrate a system that could identify individuals based on the dynamics of the face during different facial expressions. The results achieved scores varying from 68% to 90%.

Osia, N., and Bourlai, T. (2012). "Holistic and Partial Face Recognition in the MWIR Band using Manual and Automatic Detection of Face-based Features".

In this paper, focus was on some problems of middle-wave infrared facial recognition. It also presented a new approach based on holistic faces, sub region faces and the combination as well, such as eye, nose, and chin regions. The first step in the approach involved feature extraction through skin segmentation, eye detection, inter-ocular and geometric normalization of the entire face dataset. The second step included the application of statistically-based physiological feature extraction algorithm in order to extract features that include wrinkles, veins, edges and perimeters of facial characteristics using anisotropic diffusion and to hat segmentation. The third step, detection of fiducial points is performed either manually or automatically using different detectors such as a fingerprint-based minutiae detector, Scale-Invariant Feature Transform (SIFT) detector, and the Speeded Up Robust Feature (SURF) detector. As a last step, face matching was performed, utilizing fiducial points originally detected where end points and branch points on the face are filtered using the maximum pixel distance allowed between two matching points. Matching experiments are performed by using either the whole or sub-regions of the human face.

The result obtained for facial matching on holistic faces accuracy was 95%.

Maheshkar, V., et al. (2012). "Face Recognition using Geometric Measurements, Directional Edges and Directional Multiresolution Information".

In this paper, the authors proposed the extraction of geometric measurements of face regions for different directional information and multi-scale information offered by Real Dual Tree Discrete Wavelet Transform (RDT-DWT) to generate facial features for face recognition. The proposed scheme calculates feature sets: geometric measurements such as the area measures of eye, nose and mouth, horizontal, vertical, and diagonal directional edge information and multi-scale information using whole face information. Existing feature-based or local features based methods, depend on characterization of individual facial features such as eyes, nose, mouth and their geometrical relationships. The proposed approach automatically calculates the measures of important areas of interest that describe the information present in an individual face image. The area of different segmented regions is calculated that describes the information of facial components. The proposed geometric features, directional information using Fast Wavelet transform and multi-scale image formation gives the rotation, pose and expression invariant face recognition.

Fusion of various generated features improves the recognition considering the different segmented face information. The success of the scheme is the automatic calculation of various geometric features, directional edge information and whole face information. The main features of the proposed approach are detection of important regions, calculation of geometric features and fusion with information offered by edge and multi-scale information.

The result of the proposed approach geometrics measurements with (RDT-DWT) was 95%.

Lin, C. F., et al. (2013). "Accuracy Enhanced Thermal Face Recognition".

The authors in this paper focused on Face recognition with thermal image that has begun to attract significant attention gradually since illumination of environment would not affect the recognition performance. However, the recognition performance of traditional thermal face recognizer is still insufficient in practical applications. The authors presented a novel thermal face recognizer employing not only thermal features but also critical facial geometric features which would not be influenced by hair style to improve the recognition performance. A three-layer back-propagation feed-forward neural network was applied as the classifier. Traditional thermal face recognizers only use the indirect information of the topography of blood vessels like thermogram as features.

To overcome this limitation, the proposed thermal face recognizer can use not only the indirect information but also the direct information of the topography of blood vessels which is unique for every human. Moreover, the recognition performance of the proposed thermal features would not decrease even if the hair of frontal bone varies, the eye blinks or during nose inhale/exhale.

The experimental results showed that the proposed features are significantly more effective than traditional thermal features and the recognition performance of thermal face recognizer was improved.

Budzan, S., and Wyzgolik, R. (2013). "Face and Eyes Localization Algorithm in Thermal Images for Temperature Measurement of the Inner Canthus of the Eye".

In this paper, a highly accurate and fast algorithm for detection and localization of the face and the inner canthus of the eye temperature measurement is presented. The algorithm employs several methods that include a combination of the template-matching, knowledge based and morphological methods besides the modified Randomized Hough Transform (RHT) in the localization process in addition to growing segmentation to increase accuracy of the localization algorithm. Such approach appears to improve the time complexity of the RHT and the inner canthus localization accuracy.

In many solutions, it is found that the localization of the face and/or eyes is realized by manual selection of the regions of the face and eyes followed by the measurement of the average temperature in the region. Furthermore, the article also deals with the experimental investigations and their results; this allowed the evaluation of the effectiveness of the developed algorithm.

An important issue is presented regarding the standardization of measurement, necessary for proper temperature measurement with the use of infrared thermal imaging.

Nakanishi, Y., et al. (2013). "Robust Facial Expression of a Speaker using Thermal Image Processing and Updating of Fundamental Training Data".

In this paper, a method for facial expression recognition of a speaker is developed. The main attention of the work focused on the development of how to detect human feelings or mental states and under widely varying lighting conditions. In order to perform facial expression recognition, three static images were selected at the timing positions of just before speaking and while speaking the phonemes of the first and last vowels. Then, for facial expression recognition, only the static image of the front view face was used. Frequent updates of the training data were found rather time-consuming. To overcome this disadvantage, it is found that the classifications of ''neutral'', ''happy'', and ''others'' were efficient and accurate for facial expression recognition with regards to reduce the time for updates.

When the proposed method is employed with updated training data of ''happy'' and ''neutral'' after an interval of approximately three and a half years, the facial expressions of two subjects were discernible with 87.0 % accuracy for the facial expressions of ''happy'', ''neutral'', and ''others'', when exhibiting the intentional facial expressions of ''angry'', ''happy'', ''neutral'', ''sad'', and ''surprised''.

Wang, S., et al. (2013) "Eye Localization from Thermal Infrared Images".

In this paper, the problems of eye localization in infrared spectrum are discussed. An automatic eye localization method is proposed from long wave infrared thermal images, both with and without eyeglasses. The localization process was derived from the knowledge of facial structure and temperature distribution. For eye localization in samples with eyeglasses, the valleys and peaks of projection curves were used to provide the information of edge regions. An approach for eye localization in samples without eyeglasses is made by proposing a structure consisting of 15 sub regions in order to extract the Haar-like feature to capture the temperature distributions of the eyes and the regions. Adaboost algorithm selected eight classifiers that were derived from the combination features selected by the process for left and right eye. The proposed algorithm was implemented on two databases Natural Visible and Infrared facial Expression database (NVIE) and Equinox.

The results of eye detection with NVIE database was 99.35 % and with Equinox database 95 %.

Guzman, A. M., et al. (2013). "Thermal Imaging as a Biometrics Approach to Facial Signature Authentication".

This paper presented a novel approach for biometric facial recognition that is based on unique feature extraction and similarity measurements from multiple thermal images. In order to extract feature from the thermal images to create thermal signatures or vasculature information, and identify the individuals, a morphological image processing technique was applied.

It utilized four images that were taken at various instants of time in order to ensure that unforeseen changes in the vasculature over time did not affect the biometric matching process, remembering that the authentication process relies only on consistent thermal features. For such purpose, thirteen subjects were chosen for the testing of the developed technique on thermal imaging system. The registration process was conducted by the use of the linear image registration tool. The matching process was realized via unique similarity measures. The signatures were employed in order to create templates and further matched using similarity measures. The matching process was done twice between templates and signatures based on the Euclidean-based similarity measure.

For the skeletonized signatures and templates, the accuracy was found to be 88.46%, while using the Manhattan-based similarity measure yielded 90.39% accuracy

Mostafa, E. et al. (2013). "Face Recognition in Low Resolution Thermal Images".

An automated method is presented to improve rotation invariant and fast approach of facial features from thermal images. This approach involves a combination for both appearance and geometric information to detect the facial features. When using Haar features and AdaBoost algorithm, a texture based detector was utilized. The relation between the facial features was implemented by the use of a complex Gaussian distribution that is based on extracting a local signature around facial features, which is invariant to rotation. A comparative study for the different signature techniques employing different facial image resolutions was presented.

This study yielded results that suggest the minimum facial image resolution in thermal images can be used in face recognition. Guideline for choosing a good signature is provided in the paper also. The study included the LBP and Scale Invariant Feature Transform (SIFTS), due to their good performance in former face recognition studies. Recently Binary Robust Independent Elementary Features (BRIEF) has been recently proposed as an efficient alternative to SIFT and Speeded-Up Robust Features (SURF).

Evaluation of the recognition rates of the three different signatures was performed. Finally, in order to highlight the accuracy of the proposed automatic detection, the manually annotated features and the recognition performance, using the different signatures, are computed on the basis of both manually annotated features and automatically obtained ones.

Zaeri, N. (2014). "Component-Based Thermal Face Recognition".

In this paper, the author presented a new technique for face recognition that exploits the local statistical characteristics of a thermal image. The “whole” face image is divided into components of different sizes. The statistical features of these components, beside the “whole” image are combined together using fusion methods. Decision level fusion finds a combination of multiple statistical patterns to produce an integrated result that is enhanced in terms of information content for pattern recognition and classification.
Local representations offer robustness against variability due to the changes in localized regions of the objects. The proposed feature vector consists of different moments’

calculations and thermal components' histograms. The features found from local analysis are less sensitive to illumination changes, easier for estimating the rotations, have less computational burden and have the potential to achieve higher correct recognition rates.

The experimental results reveal that the new system can achieve a success rate of 96.4%.

Chapter Three
Implementation of the Proposed Model

Chapter Three

Implementation of the Proposed Model

3.1 Overview:

Thermal face recognition has become an area of growing research interest and very powerful types of biometrics for identification and verification. Generally, thermal images represent the heat patterns emitted by an object; in the case of the face, its vein and tissues are considered unique for each person, consequently face thermal images become unique.

Thermal images are very useful under all lighting conditions including total darkness or in the case a person is wearing a disguise, such as (fake nose, wig, makeup, plastic surgery and so on) (Akhloufi, M. et al. 2008).

In this study, the aim of prime importance is to extract features from thermal face images to identify the person by using feature-based methods.

There are many types of feature extraction techniques especially used for thermal face recognition; most common types are based on Appearance-based methods. Some of the drawbacks of these methods are the background difference in illumination, image head size and orientation in addition to variations in light intensity. In thermal images there exist difficulties in locating the eyes and as for identification extracting and matching the thermal contours present further difficulties.

3.2 Thermal Face Recognition Proposed Model:

In this study, a model is proposed for thermal face recognition that involves extracting features based on features methods. This model is divided into five modules with each module involving several steps. The block diagram of the proposed model is shown in figure (3.1). The proposed model modules are listed as follows:

6. *Acquisition Module (replaced by IRIS Thermal/Visual Database).*
7. *Pre-processing Module.*
8. *Detection Module.*
9. *Features Extraction Module.*
10. *Classification Module.*

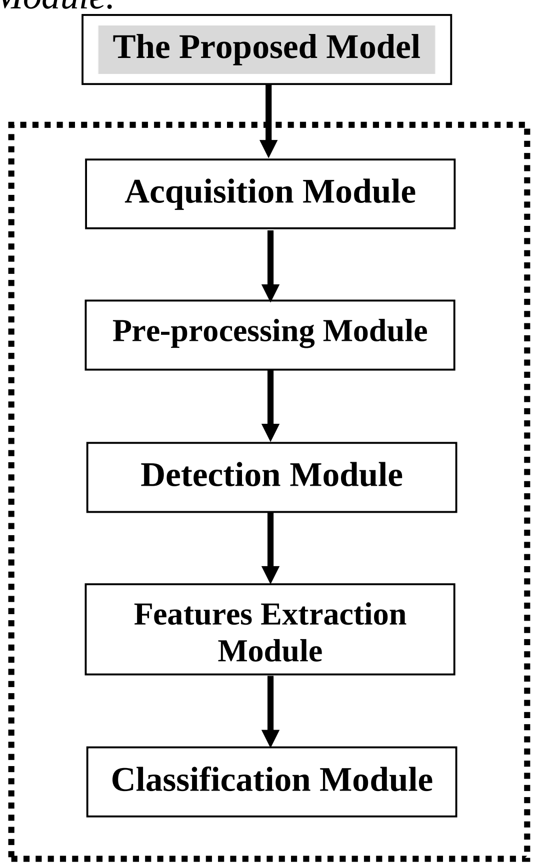


Figure (3.1): Block Diagram of the Proposed Model

3.2.1. Acquisition Module (replaced by IRIS Thermal/Visual Database):

The growing interest of employing thermal face images in face recognition has prompted the need for face image databases. In view of the high cost of thermal camera, an alternative approach was used by utilizing available public thermal face database, IRIS (Imaging Robotics and Intelligent System) Thermal / Visual database (http://www.vcipl.okstate.edu/otcbvs/bench/). The main features of the IRIS database are listed as follows:

1. Sensors used: (Thermal) Raytheon Palm-IR-Pro. (Visible) Panasonic WV-CP234
2. Its contents include images of 30 individuals (28 men and 2 women).
3. The imaging and recorded conditions (camera parameters, illumination setting, camera distance).
4. Total of 176-250 images per person and 11 images per rotation (poses for each expression and each illumination) are captured.
5. Database images have bmp-format color images of 320 × 240 pixels in size.
6. The subjects are recorded with 3 different facial expressions: Exp-1 (Surprised), Exp-2 (laughing), Exp-3 (Anger) and 5 different illuminations Lon (left light on), Ron (right light on), 2on (both lights on), dark (dark room), off (left and right lights off) with varying poses.
7. Size of this database is 1.83 GB.
8. A total of 3058 images are available; 1529 images are thermal and other images are visual.
9. This database includes disguised faces too. Samples of images with different facial expressions, different illumination conditions, and different disguised faces.

3.2.2. Pre-processing Module:

In this module, several processes are applied to improve the quality of the thermal images because these images have low resolutions that have been acquired under different background and conditions as shown in figure (3.2).

Figure (3.2): Thermal Face Images before any Pre-processing

In this module, the subset of the images are used for different persons, different facial expressions (surprised, laughing and anger) and under different illuminations conditions.

To obtain good thermal face images for processing in this module, three steps are presented in order to enhance and improve the face images; the block diagram of the pre-processing module is shown in figure (3.3).

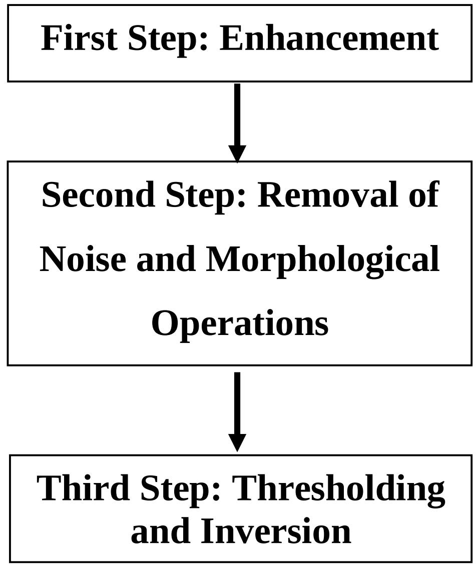


Figure (3.3): Block Diagram of Pre-processing Module

3.2.2.1 First Step: Enhancement

The purpose of image enhancement is to process the thermal images to reproduce more suitable images than the original images for the proposed model because the input thermal images are of very poor resolution; therefore, necessity demands enhancement of the images. This step involves many operations, filtering and conversion of images are applied due to the fact that the input face images to the model possess low resolution; this demands enhancement of these images throughout this part of this module.

Each process is clarified and explained. The initial images before any pre-processing processes are color-images; the first step is converting the images to grayscale. The grayscale image consists of a single channel that represents several factors, such as intensity, brightness, or density of the image, and the range of the color, while normally the shades are of gray level.

The brightness correction adjusts the pixels brightness by increasing or decreasing every pixel range value from (0-255). Gamma correction is typically used to adjust for differences in the way monitors display brightness and colors. The value of gamma is less than 1 in the case when the output is bright and if greater than 1 the output is darker. The purpose behind contrast stretching is to increase the range of the gray levels in the image being processed because low-contrast images can result from poor illumination, lack of dynamic range in the imaging sensor, or wrong setting of a lens aperture during image acquisition (Nixon M. S. and Aguado A. S. 2008).
As listed below, the enhancement algorithm is applied together with more details regarding the techniques; some sample results of the enhanced thermal face images, are shown in figure (3.4).

ENHANCEMENT ALGORITHM (M, Q)

// Input: color thermal image (M), Output: enhanced thermal image (Q) //

M ← image

N ← grayscale (M)   //convert the color image to grayscale//

O ← brightness correction (N) // this filter adjusts the pixels brightness by increasing or decreasing every pixels value by the specified adjustment value //

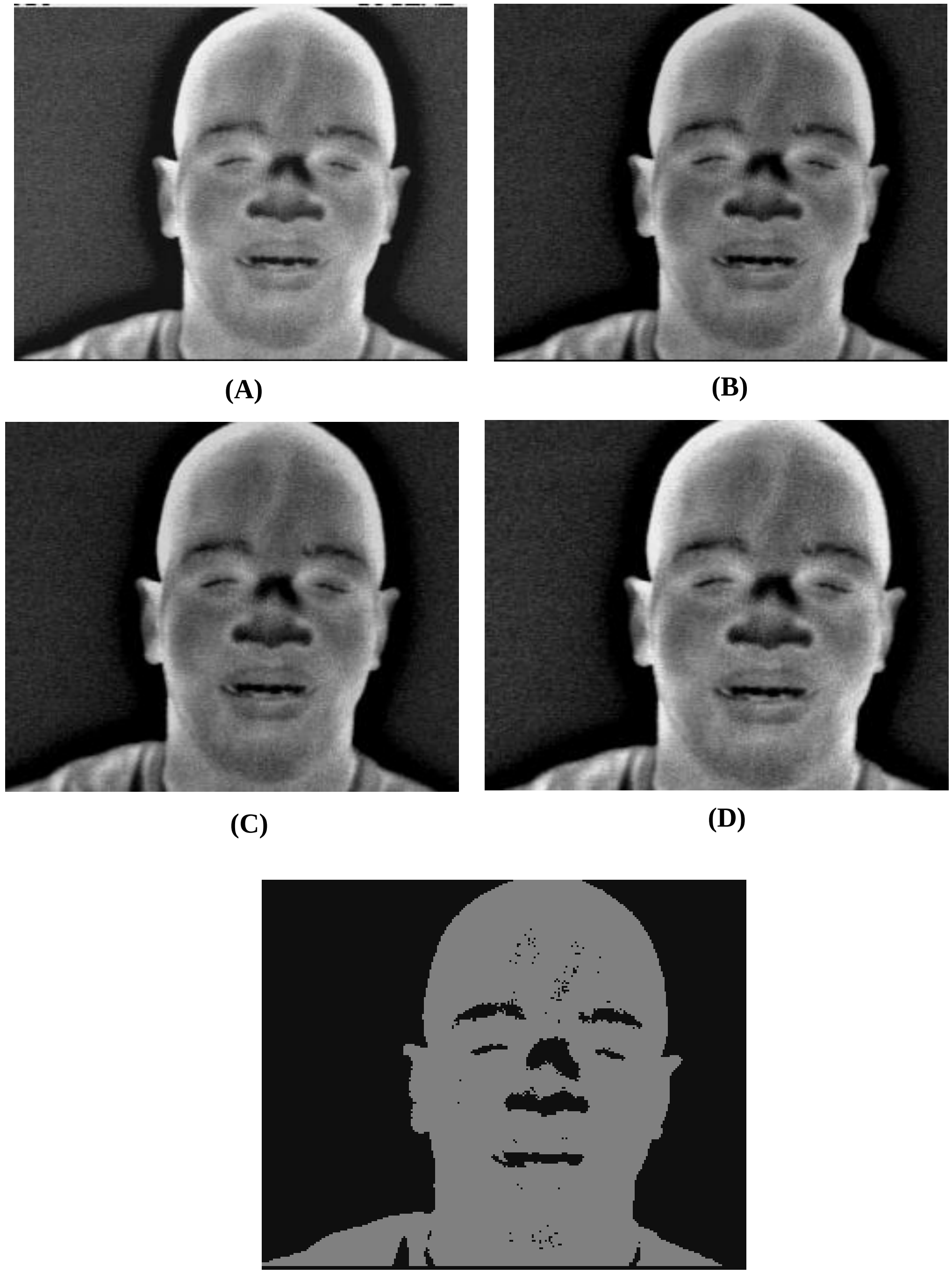
P ← gamma correction (O)   // gamma correction controls the overall intensity of the image and maps the value into new values; if gamma value is less than 1, the image output will be brighter and if gamma value is greater than 1 the image output will be darker //

K ← contrast stretch (P) // stretch the range of intensity value in an image to increase the contrast, this technique is a simple image enhancement technique and this technique is also called normalization//

L ← format 24bppRgb (K) // convert the image from 8 bpp to 24 bpp RGB because the next operation accepts 24 bpp //

Q ← color image quantizer (L) // color image quantizer process to reduce the color image to the specified number (2) //

Return (Q)



(A) (B) (C) (D) (E)

Figure (3.4): (A) Grayscale Filter, (B) Brightness Filter, (C) Gamma Filter, (D) Contrast Stretch Filter, (E) Color Image Quantizer.

3.2.2.2. Second Step: Removable noise and Morphological Operations

Following the enhancement step, the images still retained noise that will undoubtedly have an effect on the process of this model. In this step, many operations are applied to reduce noise. There are different types of filters used to remove noise, it is impossible to design a filter that removes any noise but keeps all the important image structures intact, because no filter can discriminate which image content is important to the viewer and which is not. The most effective filter rather than other filters is the median filter. This filter is good for cleaning salt and pepper noise, the blurring is minimized and the edges stay sharp. The process of median filter defines the symmetric mask and replaces every image pixel by the median of the pixels in the corresponding filter region.

Other operations are used to reduce noise, such as morphological operations. The purpose of morphological operations is how to extract the components of the face image that are useful in the representation and description of regions shape, these operations use a set of mathematical tools to extract useful description. Erosion and dilation operations are applied in this step. Dilation can repair breaks and intrusions, erosion can split apart joined object and can strip away extrusions (Gonzalez R. C. and Woods R. E. 2002).

As listed below, the median filter and morphological operations algorithm were applied with some sample results of the thermal face images with minimum noise, are shown in figure (3.5).

MEDIAN FILTER AND MORPHOLOGICAL OPERATIONS ALGORITHM (X, J):

// Input: enhanced thermal image (X), Output: thermal image with minimum noise (J) //

X ← image

V ← format 24bppRgb (X) // convert the image from 4 bpp to 24 bpp RGB, because the output image for the previous step was 4 and median filter with morphological operations needs 24 bpp image //

O ← median filter (V) // median filter is used to reduce salt and pepper noise by using mask

(3 × 3) //

Y ← (3 × 3) // (3 × 3) element structure is used with the morphological operations //

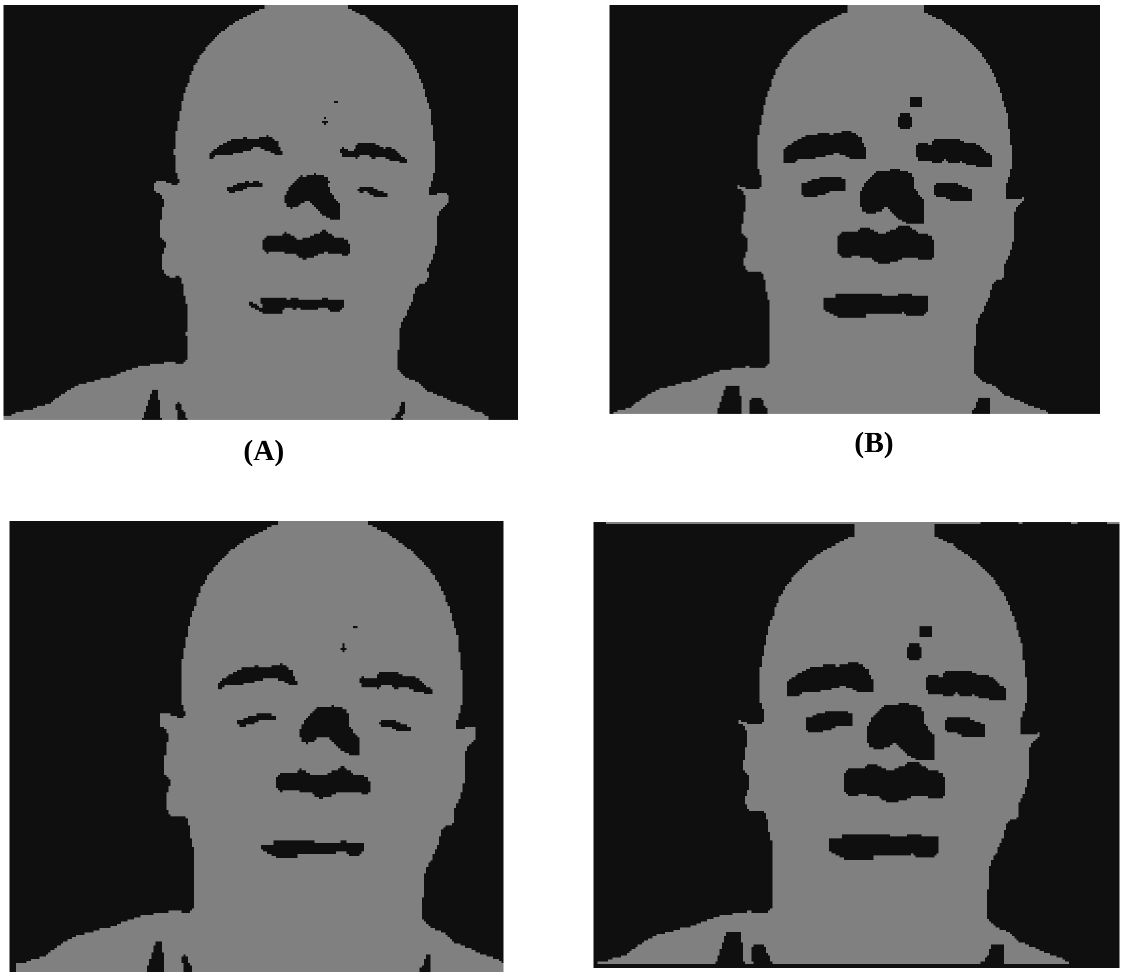
M ← O Y ⊖ // erosion operation provides ability to

remove noisy pixels or shrink objects//

Z ← M ⊕ Y // dilation operation allows to grow separate objects or join objects //

J ← Z Y ⊖ // erosion operation //

Return (J)



(A) (B)

(C) (D)

Figure (3.5): (A) Median Filter, (B) Erosion Operation, (C) Dilation Operation, (D) Erosion Operation

3.2.2.3 Third Step: Thresholding and Inversion

In the course of the thresholding and inversion step, SIS thresholding is applied to produce thermal images having just two colors (black and white). SIS threshold calculates the threshold automatically by using simple image static method for each pixel. The inversion process is applied just for inverting the colors after thresholding process; the idea for this process is to provide the detection module (Burger W. and Burge M. J. 2009). As listed below, the SIS thresholding and inversion algorithm are applied and sample result of the thermal face image is just black and white, as shown in figure (3.6).

SIS THRESHOLDING AND INVERION ALGORITHM (X, M)

// Input: thermal image with minimum noise (X), Output: thermal image with white object to the features regions (M) //

X ← image

Y ← grayscale (X)   // convert the image from 24 bpp to grayscale //

Z ← SIS threshold (Y)   // automatic SIS thresholding //

M ← invert (Z)   // invert the color image as the white background, black face region and white for the blob region or features regions //

Return (M)

Figure (3.6): Thermal Image during SIS Thresholding and Inversion Step

3.2.3. Detection Module:

The detection module follows immediately after the implementation of the pre-processing module, where the images are prepared for detection module that detects the blob feature regions. The detection module uses blob detection that is based on connected component analysis algorithm to detect all the connected pixels with the same color index as a separate blob object and this algorithm treats all pixels with value less or equal to background threshold as background but pixels with higher values are treated as object pixels (Zheng, L., et al. 2010). Blobs can be counted, extracted, filtered and obtain their dimensions. During the blob detection process, it can set blobs filter options by their size to detect the blobs of interest based on the minimum, maximum width and height for each blob. As listed below, the block diagram of the detection module is shown in figure (3.7), while the blob detection algorithm and sample result that show the blob regions of the face image are shown in figure (3.8).

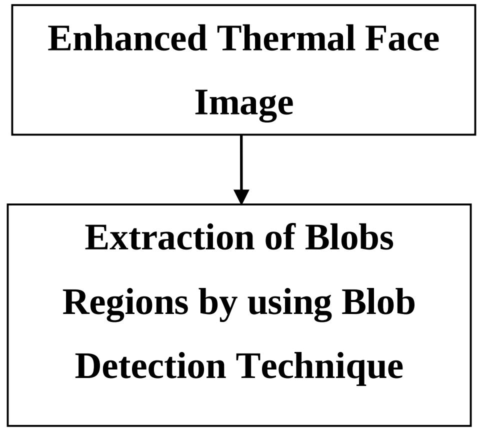


Figure (3.7): Block Diagram of Detection Module

BLOB DETECTION ALGORITHM (X, blobs)

// Input: thermal image after pre-processing operations (X), Output: blobs information (blobs) //

bc ← blob counter // blob counter is used to extract stand alone objects (blob features) //

bcminw ← bc.min width // minimum width of the blob region//

bcminh ← bc.min height // minimum height of the blob region//

bcmaxw ← bc.max width // maximum width of the blob region//

bcmaxh ← bc.max height // maximum height of the blob region//

bcblob []← [(bcminw: bcminh), (bcmaxw: bcmaxh)]

X ← image // thermal image after the pre-processing operations //

Z ← bcblob.ProcessImage (X) // extract the blob that treats all pixels with values less or equal to background, the image processing filter treats all white pixels as object and all black pixels as background//

Z1← Z. size

Z2← object order (Z1) // ordering the blobs based on the size of the blob//

blobs ← get objects information (Z2) // get the objects information

blobs and each blob contains one of the features //

Perform the extracting features module // called (extract the whole region algorithm) //

Return (blobs)

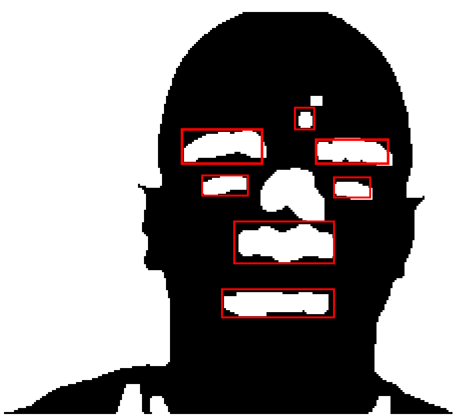


Figure (3.8): Detect the Blobs Regions

3.2.4. Features Extraction Module:

As a follow-up to the detection module, the blobs are prepared for this module to extract features based on feature-based methods with the aim of detecting a set of geometrical features on the face, such as the eyes, eyebrows, nose and mouth. These features can be characteristic and relations such as center point, distances, and angles between the feature blobs that are used as descriptors for this module.

In the course of this module, the extracted blobs from the previous module are used to compute the center point for each blob and find the relations between the blobs in order to extract the distances and slopes. To ensure the model to be more accurate, it will try to find the best way to extract the whole region that contains all blobs, the purpose of this whole region is to find the pair of eye regions. Extracting module is divided into three steps. The block diagram of the features extraction module is shown in figure (3.9).

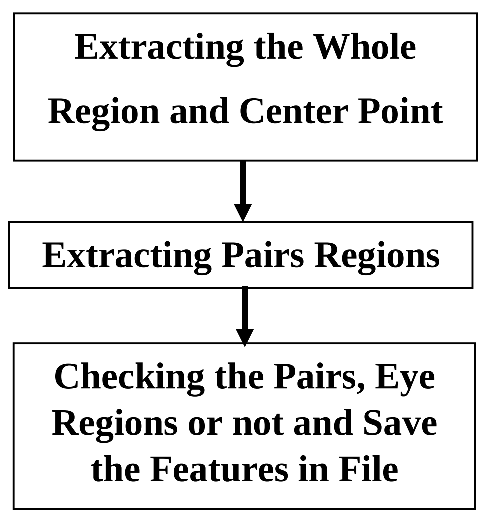


Figure (3.9): Block Diagram of the Features Extraction Module

3.2.4.1. Extract the Whole Region:

Following the blob detection module that extracts the blob regions, now it will try to determine the work of the module to extract the specific features. Through this step, it will determine the purpose to extract the whole region. Firstly it computes the center point for each blob and secondly builds the whole region that passes through the center point for the latest blobs from all sides. The purpose of this whole region is to check the eye pairs as will be seen in the next step. Finally the output for this step is the listing of the features such as (distances between the center points, center points, distances eye pairs and slopes). As listed below, the algorithm of the whole region and the sample result are shown in figure (3.10).

EXTRACT THE WHOLE REGION ALGORITHM (blobs, Ar)

// Input: rectangular blob regions (blobs), Output: list that contains all the extracted features (Ar) //

Ar ← list // Ar is a list file that contains all the information about the features that are extracted from the images such as center points, slopes, distances… etc //

Z3 ← (blobs.index) // the index for each blob //

IF (Z3 > 0) then

Rec ← whole region // extract the whole region that contains all blobs, this rectangle is used for a specific reason that will be seen during the next processes//

FOR i = 0 : Z3

centerpoint ()← new point ((blobs[i].rectangle. left + blobs[i]. rectangle .width/ 2) , (blobs[i]. rectangle. top + blobs [i]. height/ 2)) // in this step, the center point for each blob will compute //

IF (Rec.X > centerpoint.X || Rec.X ==0) then

Rec.X = centerpoint.X

END IF

IF (Rec. width < centerpoint. X || Rec. width ==0) then

Rec. width=centerpoint.X

END IF

IF (Rec.Y > centerpoint.Y || Rec.Y==0) then

Rec.Y=centerpoint.Y

END IF

IF (Rec.height < centerpoint. Y || Rec. height==0) then

Rec. height =centerpoint. Y

END IF

MinY ← minimum Y in the image

IF (MinY > centerpoint.Y) then

MinY = centerpoint.Y

END IF

cent[] ← (Rec.height, Rec.width, Rec.X, Rec.Y, centerpoint (X,Y))

// cent array returns the value of the whole region and the center point for each blob for the pairs algorithm //

Perform Pairs algorithm // called (pairs algorithm) //

END FOR

Perform Pairs checking algorithm // called (pairs checking algorithm) //

END IF

RETURN (Ar)

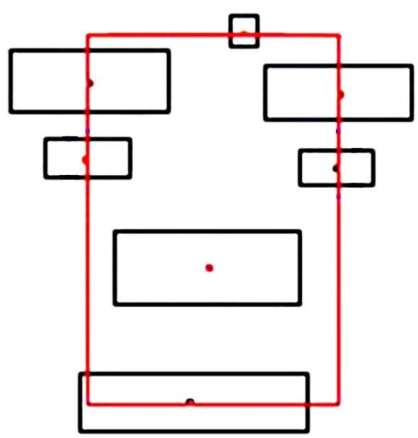


Figure (3.10): Sample Result after Extracting the Whole Region and the Center Point for each Blob

3.2.4.2. Extract the Pairs Regions:

In this step detects the pairs regions such as eyebrows region and which may contain eyes region as will be seen in the next step which involves the manner how to check if it is eyes region or not. The algorithm of pairs is listed below.

PAIRS ALGORITHM (cent, subAr)

// input: values of the whole region and the center points for each blob (cent), output: subset of the original (Ar) that contains the center points, slope and distance (subAr) //

Pairs ← new list   // list of the pairs that may contain eyes region or another pairs such as eyebrows, in the next algorithm in which check is performed if eye regions or not//

subAr []← subset of the original array // (subAr), subset includes the center point and center point2 for the pairs, slope and distance//

P ← new point

FOR j = 0 : Z3

centerpoint2 () ← new point ((blob[j]. rectangle. Left +blob[j]. rectangle. width) / 2, (blob[j]. rectangle. top +blob[j].rectangle. height) /2)

IF   (centerpoint != centerpoint2)   then

L ← draw line (centerpoint, centerpoint2)

Dist ← centerpoint. Distance to. centerpoint2

S ← L. Slope

IF (Math.Abs (S) <= 0.15) then

Pairs. add []← (centerpoint, centerpoint2)

END IF

P[X1, Y1] ← centerpoint [X1, Y1]

P[X2, Y2] ← centerpoint2 [X2, Y2]

P.Slope ← S

P.Distance ← Dist

subAr[].Add ← P

END IF

END FOR

RETURN (subAr)

3.2.4.3. Checking of the Pairs Regions:

In this step checks the pairs regions if it is an eyes region or not employing many conditions as will be seen in the algorithm, as listed below together with sample result as shown in figure (3.11).

PAIRS CHECKING ALGORITHM ((Pairs, subAr, cent), Ar)

// input: (Pairs, subAr, cent), output: (Ar) //

IF (Pairs !=null) then

FOR iP=0 : Pairs.count

MaxDist ← maximum distance to the pairs

distance ← Math.abs (Pairs[iP][0]. Distanceto(Pairs[iP][1]))

If Cond == true then // the Cond is a set of many conditions that contains (the first pair set in the first quarter of the image, the second pair set in the second quarter, the (Y) coordinates of the pairs are the maximum (Y) in the image, the last condition is the distance between the pairs which is greater than the width / 2 of the cent) //

Min[] = Pairs [iP]

MaxDist = distance

END IF

END FOR

IF (Min!= null) then

Dist[]← Math.Abs (Min[0] . distanceTo Min[1])

FOR iL=0: Ar.count

IF (Ar[iL].X1==Min[0].X &&

Ar[iL].Y1==Min[0].Y &&

Ar[iL].X2==Min[1].X &&

Ar[iL].Y2==Min[1].Y) then

Ar[iL].IsEye ← true

END IF

Ar [iL].DistanceRation ← Ar[iL].distance/Dist

END FOR

FOR iL=0:Ar.count

Ar[iL].Distance from top ratio ← Math.Abs(Ar[iL].Y1/min.Y)

END FOR

RETURN (Ar)

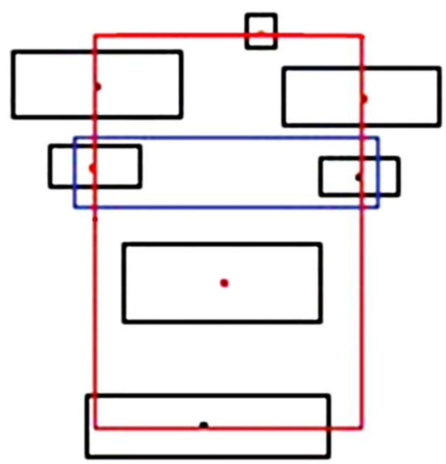


Figure (3.11): Sample Result to Detect the Eye Region

3.2.5. Classification Module:

As a follow-up to the features extraction module, the features are prepared for this module in order to match the person, based on different images of the same person, different facial expressions (surprised, laughing and angry) and under different illumination conditions. Through the work and exploring the results for the features, a method for matching process between two persons will be presented, based on different expressions and illuminations of the same person followed by creating a key or ID that relates to the same person.

This key is stored to be used for another matching process between different persons in order to decide if there is matching or not. The classification module algorithm is listed below.

CLASSIFICATION ALGORITHM ((M, N), T)

// input: two thermal images (M, N), output: compound key (T) //

M ← image

N ← image

Perform enhancement algorithm (M,N) // called (enhancement algorithm) //

Perform median filter and morphological operations algorithm (M, N) // called (median filter and morphological operations algorithm) //

Perform SIS thresholding and inversion algorithm (M, N) // called (SIS thresholding and inversion algorithm) //

Perform blob detection algorithm (M, N) // called (blob detection algorithm) //

Perform extract the whole region algorithm (M, N) // called (extraction the whole region algorithm) //

Perform pairs algorithm (M, N) // called (pairs algorithm) //

Perform pairs checking algorithm (M, N) // called (pairs checking algorithm) //

Ar2[] ← array of features to image (N)

[A] ← Size (Ar1) // Ar is corresponding size of (Ar1 and Ar2)//

FOR i=1: A

W ← weight // the weight is multiplied for each feature to increase the performance, it will extract the weight for each feature based on the difference between the same feature for two images of the same person //

P [i] ← Ar1 [i] – Ar2 [i] // extract the difference between the same feature for two images that relates to the same person //

O [i] ← (Ar1 [i] + Ar2 [i] / 2) // extract the average of the feature //

R [i] ← Abs (P [i] - O [i])

Q [i] ← R [i] * W // multiply the weight for each feature by the amount of the previous statement//

END FOR

T ← sum (Q)

RETURN (T)

3.3 Results:

The results obtained when processing the images using the proposed model in this study, by taking the number of persons and number of samples used, the percentage rate obtained are tabulated as shown in Table (3.1).

Table (3.1): Results

Number of Persons	4	4	3
Number of Samples	50	37	35
Percentage Rate	75 % - 85 %	65 % - 75%	55 % - 65%

Chapter Four

Conclusions and Future Work

Chapter Four

Conclusions and Future Work

4.1 Overview:

In our world, the security has become a very high priority especially in the field of identification problems to distinguish one person from another according to their characteristics. To achieve more reliable identification, it should use something that really characterizes the given person. Biometrics offer automated methods to identify the principle of measurable physiological or behavioral characteristics. The characteristics are measurable and unique. One of the important fields for the physiological characteristics is the thermal face recognition.

Thermal face recognition has recently become an area of growing interest to the researchers. The main problem in the thermal face recognition is how to extract the features that distinguish one person from another and to obtain a rate of recognition. In this study, a model is designed to extract the features from thermal images to identify the person based on different expressions and illuminations and to work on the best way to obtain good recognition rate.

This chapter summarizes the details of the proposed model under the conclusions' and presents some suggestions for future work to develop the approach presented in this thesis.

4.2 Conclusions:

The best way to extract features for thermal face images cannot be easily determined without employing evaluation of face recognition algorithms. The evaluation can help in achieving more reliable set of face features and to increase the performance of the overall model.

In this study, a model is presented to extract features that are very important in recognizing thermal facial image. During the process of the model, it uses IRIS database. In the pre-processing module, it uses many enhancement filters to enhance the thermal images, morphological operations and noise removing filters. In the detection module, blob detection is employed to detect the features blobs regions.

The important module in this study is the features extraction module. In view of some of the drawbacks of appearance-based methods for thermal face recognition which includes background difference in illumination, image head size and orientation in addition to variations in light intensity. In thermal images, there exist further difficulties in locating the eyes when extracting and matching the thermal contours. To overcome these difficulties, it uses feature-based methods to extract features that are a set of geometrical features such as distances, slopes and center points. It is noteworthy to mention that in the classification module, an approach was explored during this study in the matching between two persons based on different expressions and illuminations of the same person to create a key or ID that is related to same person. This key is suitable for the matching process and especially for matching different persons.

In this study, the recognition rate derived from this model and was range between 55% to 85%. It has to be mentioned that the images in the database, used in this study, were not of the same resolution. The low rate values are attributed to the variation in the resolution of the images involved in the processing that clearly affect the performance. The high rate values verify the effect of variation in the image resolution on the rate values, otherwise all rate values were of the same order.

4.3 Future Work:

The results in this study offer some suggestions for further research in developing other approaches to calculate the values of the recognition rate. These suggestions are summarized as listed below:

1. For the detection module, SUSAN edge detector or Harris operator are to be used that may provide better results the detection of the points of interest. Following the use of these detectors k-means clustering or fuzzy c-means clustering can be used to extract only the important regions containing the features.

2. For the features extractions, it is suggested to extract the interest points for each region and connect between the points to create a triangle from which the angles between the lines are computed.
3. For the classification module, neural network method employing different models, such as back propagation or hidden markov models can be utilized.

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Appendix A

The IRIS Database Sample

Appendix A

The IRIS Database Sample

A.1 Three Different Expressions

Thermal Faces

Exp1 (Surprised) **Exp2 (Laughing)** **Exp3(Anger)**

Visual Faces

Exp1 (Surprised) **Exp2 (Laughing)** **Exp3(Anger)**

A.2 Five Different Illuminations

Left and Right Light On | Dark Room | Left Light On | Both Light Off | Right Light On

Thermal Faces

Visual Faces

A.3 Different Disguises

Mask | Sunglass + Moustache | Goggle | Wig | Sunglass + Moustache

Thermal Faces

Visual Faces

Appendix B
Example of the Proposed Model

Appendix B

Example of the Proposed Model

1. **Acquistion Module: (Replaced by IRIS Database)**

Thermal Face Image from the IRIS Database

2. **Pre-processing Module:**

❖ **First Step: Enhancement**

Grayscale

Brightness

Gamma Filter

Contrast Stretch Filter

Color Image

❖ **Second Step: Removable noise and Morphological Operations**

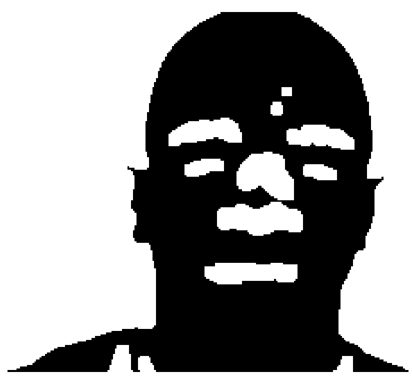
Median Filter

Erosion Operation 1

Dilation Operation

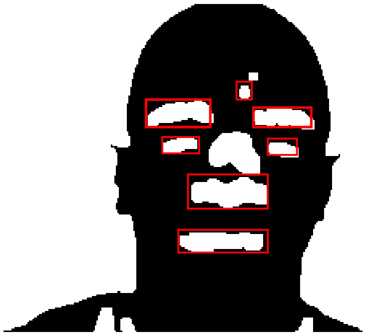
Erosion Operation 2

❖ **Third Step: Thresholding and Inversion**



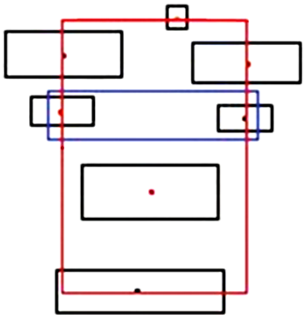
3. Detection Module:

Detect the blobs regions by using blob detection



4. Features Extraction Module

Extract the whole region, center point for each blob, extract the pairs regions, and checking if eye regions or not.



5. Classification Module:

The classification module can be depicted in a series of steps describing the processing and matching of different images of the same person, different facial expressions (surprised, laughing and angry) and under different illumination conditions.

W ← weight // the weight is multiplied for each feature to increase the performance, it will extract the weight for each feature based on the difference between the same feature for two images of the same person //

P [i] ← Ar1 [i] – Ar2 [i] // extract the difference between the same feature for two images that relates to the same person //

O [i] ← (Ar1 [i] + Ar2 [i] / 2) // extract the average of the feature //

R [i] ← Abs (P [i] - O [i])

Q [i] ← R [i] * W // multiply the weight for each feature by the amount of the previous statement//

T ← sum (Q)