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Memory

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Submitted by:

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Theme

Biometric modality characteristics extraction using Sugeno fuzzy model

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Dedication

All praise to Allah, today we fold the days' tiredness and the errand

summing up between the cover of this humble work

To my dear mother

To the big heart my dear father

To my dear grandmother and my grandfather

To my supervisor: Ms tedjani zakaria and ben said khaled

To the people who paved our way of science and knowledge

All our Professors Distinguished

To the taste of the most beautiful moments with my friends

(aicha, madjeda, hayat, bouthaina, Fatima ,houda, zohra)

Soumia

Dedication

To my dear mother and my father To my sister and my brother

To my friend and my fiancé Salhi houssam

And to all my family members, and more

Particularly To all my dear friends and Colleagues

(Soumia, madjeda, hayat, bouthaina, Fatima ,houda,zaineb)

And to all who taught me throughout my school life

Aicha

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We wish to extend our genuine sincere appreciation to my special friends, and special thanks to all the family of **BELALEM** and **HELIOUA**

Finally, a special word of appreciation and sincere feelings of being very grateful and lucky to all the members of the jury who accepted to evaluate.

ملخص

يعتبر النظام البيوميتري طريقة فعالة في مجال تحديد الهوية التلقائي, كما انه يلعب دورا مهما في هذا المجال, هذه المذكرة تعالج واحدة من أهم النظريات البيوميترية المتعلقة بتحديد الهوية الشخصية باستخدام تقنية راحة اليد المأخوذة من قاعدة البيانات (polyU), العناصرالتي تنتمي إلى الصورة المعالجة والتي تخص راحة اليد تم تحديدها باستخدام نظام المنطق الضبابي وذلك على مستوى مرحلة استخراج الصورة أو الميزة بمعنى أدق ويتم تحسين النتائج وجعلها أكثر دقة باستخدام نظرية التدرج (gradient).

يتم تنفيذ التجربة باستخدام برنامج ماتلاب.

Résumé

Système biométrique est un moyen efficace dans le domaine de l'identification automatique, il joue également un rôle important dans ce domaine importantes théories biométriques relatives à l'identification de l'identité personnelle en utilisant la technologie prise de palme à partir des éléments base de données (polyU), les éléments qui appartiennent au traitement de l'image, qui est pour la paume a été déterminée en utilisant le système de la logique floue et au niveau de l'extraction de la phase d'image ou d'une fonction dans le sens les résultats les plus précis sont améliorés et les rendre plus précis en utilisant la théorie du gradient (gradient).

L'expérience est réalisée en utilisant le logiciel Matlab.

Abstract

Biometrics based personal identification is regarded as an effective method for automatically recognizing, also his playing an important role in this field.

This memorandum presents one of the newer biometric approach to presences identification using palm print technology from a polyU data base, the parameters of the processed image wich belong to the palm print is treated by the fuzzy logic system at the feature extraction level and optimize the obtained result by the gradient method.

The experiment is carried out by using MATLAB software.

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LIST OF ABBREVIATIONS

FAR: false acceptance rate

FRR: False Rejection Rate

GAR: Genuine Accept Rate

EER: Equal Error Rate

ROC: Receiver Operating Characteristics

CMC: Cumulative Match Characteristic

PDA: personal digital assistant

ATM: automated teller machine

ID card: Identity document

MF: membership function

FIS: fuzzy inference system

TS: Takagi-Sugeno

CCD: Charged Coupled Device

NIR: Near-infrared

N-iter: iteration number

Nfa: Membership function numbers

T0: Threshold.

EER: equal errors rate

ROR: Rank-One recognition.

R, G, B, N: Red, Green, Blue, NIR.

General Introduction

General Introduction

" In the near future many transactions will no longer be performed by traditional methods, like face-to-face contacts or regular mail. Instead computer networks will be the new vehicles. As persons are physically separated, new and secure methods of identification and authentication are required " [1]

The human body is a sophisticated design, full of every required sense for identification, verification and authentication; and it is always on the verge to be understood in a greater extent. It is a complex structure, a splendid work of art, an ineffable allure and so vividly immaculate that it holds a true nature to remain an enigma for each and every single of us. For hundreds of thousands of years, we, as a human beings, have been keeping up with endeavor in the hope of exploring ourselves and our inner secrets. Thus, the human body and its performance scope have been uncovered on a regular basis in order to maneuver the performance for its own greater purpose and betterment [2].

Nowadays, private information (bank accounts, email passwords, credit card numbers, … etc.) is usually stored in personal mobile devices storage for example or stored in our mined. This leads to the urgent need of secured authentication mechanism. However, current authentication systems still witness weaknesses, which allow attackers to access sensitive information illegally. In order to support users with other authentication methods and take advantage of the new security systems, some research of biometric-based authentication have been conducted which bring potential results. The idea of biometrics was present since few years from now. In 14th century, China practiced taking finger prints of merchants and their children to separate them from all others, in the 19th century, an Anthropologist named Alphonse Bertillon developed a method (named Bertillionage) of taking body measurements of persons to identify them [3].

A biometric system regards a pattern recognition system acquiring biometric data from a user, extracting features from it, and comparing extracted features with Stored Template sets Biometric system is a pattern recognition system which uses physiological traits (i.e. face, palm, and iris) or behavioral traits (i.e. .speech, signature).

A biometric system may operate either in verification mode or identification mode. Traditionally biometric systems, operating on a single biometric feature which is the unimodal biometric system, who has many limitations which can be bypassed by the multimodal biometric system. In order to make the response of biometric system more efficient and fast, there is a lot of methods that can be integrated or used in biometric stratification. One of them is the method of fuzzy logic system.

In this work we will investigate the design of a feature extraction algorithm based on optimization of fuzzy system.

So, this memory is organized as following:

The main notion related to biometric systems and its evaluation will be examined in first chapter.

Biometric image modeling by fuzzy system is developed in second chapter where we will propose a design method to estimate Sugeno fuzzy model parameters.

In the last chapter, we will focus on the application of the proposed method in a palm print based biometric systems

A conclusion will be dressed at the end of this work.

Keywords: biometric systems, identification, Fuzzy Logic, Multimodal biometric systems; fusion levels,

Chapter I

Introduction to biometric systems

I.1 Introduction

Using human body recognition has been a major research focus area since traditional means of security such as ID cards and passwords are not reliable or convenient enough. Using a human body for recognition is essential for interpreting facial expressions, human emotions, intentions, and behavior, which is a key component for smart environments. Using the human body for recognition offers a non-intrusive, and perhaps the most natural, way of identification.

In this chapter we introduce the biometric system and its different modalities also we will classify the main types of biometric technologies (morphology, behavioral, biological), and their operations mode that includes the enrolment, and the recognition.

After that, we will examine biometric system performance evaluation depending on the measurements indices, then we will give some examples of its applications. We will also talk about multimodal biometric system passing by some problems of unimodal biometric system.

I.2Definition of biometrics

The term "biometrics" is derived from two Greek words bio (life) and metric (to measure) [4], Biometrics refers to technologies for measuring and analyzing a person's characteristics. These characteristics are unique to individuals hence can be used to verify or identify a person’s identity Biometric systems are based on the features morphologic (finger prints, iris, face, hand geometry, etc) or Behavioral (gait, voice signature, etc) or biological (DNA, etc) in order to recognize a person.

These characteristics are called biometric modalities that need to that need to meet the following properties [5, 6]:

- **Universality:** each person should have the characteristic.
- **Uniqueness:** the given trait should be sufficiently different across individuals comprising the population.
- **Permanence:** the characteristic should be sufficiently invariant (with respect to the matching criterion) over a period of time.
- **Measurability:** Ease of acquisition for measurement. However, in practical biometric system there are a number of other issues that should be considered , including:
- **Performance:** the recognition accuracy and the resources required to achieve that accuracy should meet the constraints imposed by the application.
- **Acceptability:** Individuals in the target population that will utilize the application should be willing to present their biometric trait to the system[5].

I.3 The main types of biometric technologies

There are several types of biometric identification modalities as shown in figure (**I.1**):

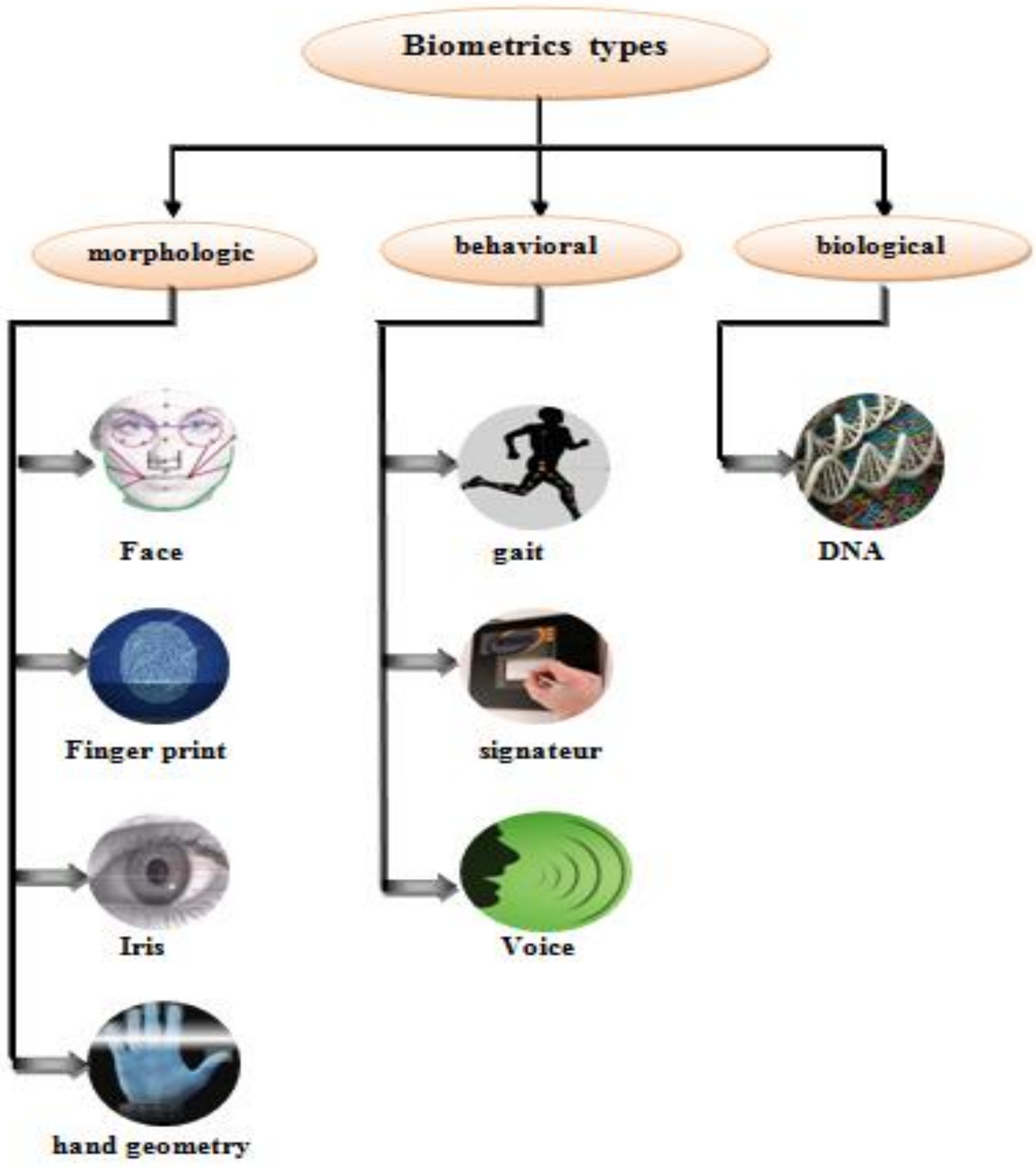


Figure I.1 The main types of biometrics modalities.

I.3.1 morphologic modalities

a) Face Recognition

It uses an image or series of images either from a camera or photograph to recognize a person. These include the position/size/shape of the eyes, nose, cheekbones and jaw line.

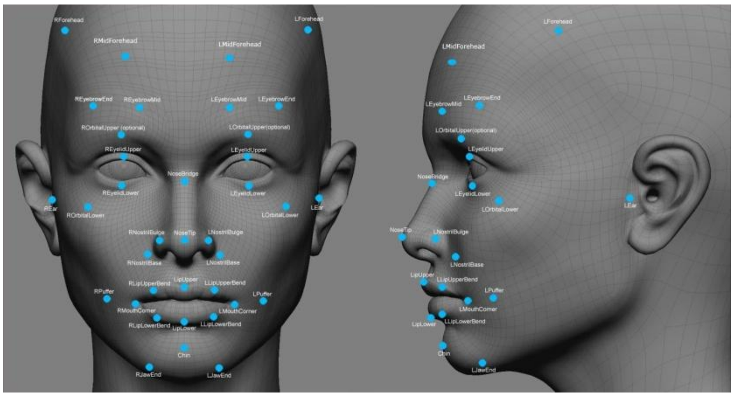


Figure I.2 Sample biometric traits: face .

b) Finger print

Finger print known as the most successful and popular method for person identification because It's easy to use and not considered a danger to the user[7].Fingerprints consist of a regular texture pattern composed of ridges and valleys. These ridges are characterized by several landmark points, cold minutiae. The minutiae points claimed to be unique to each finger; it is the collection of minutiae points in a fingerprint that is primarily employed for matching two fingerprints, this technique can be used for many applications like personal computer (PC) login security.

Figure I.3 Example of finger print biometric traits

c) Iris recognition

The analysis of the colored ring that surrounds the eye's pupil based on visible features, i.e. rings, furrows, freckles and the corona. Features and their location are used to form the Iris codes, which is the digital template.

Widely regarded as the most safe, accurate biometrics technology and capable of performing 1-to-many matches at extraordinarily high speeds, without sacrificing accuracy.

Figure I.4 Sample biometric traits: Iris

d) Hand geometry

Hand geometry systems are commonly available in two main forms. Full hand geometry systems take an image of the entire hand for comparison. Hand geometry technology is currently one of the most deployed biometrics disciplines worldwide.

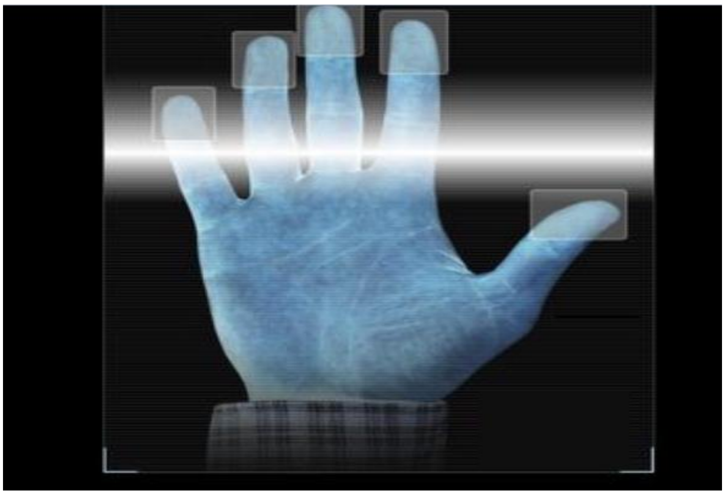


Figure I.5 Sample biometric traits: hand geometry.

I.3.2 behavioral modalities

a) Signature

The way a person signs his name is known to be a characteristic of that individual. Although signatures require contact with the writing instrument and an effort on the part of the user.
Signature is a behavioral biometric that changes over a period of time and is influenced by the physical and emotional conditions of the signatories.

Figure I. 6 Sample biometric traits: signature.

b) Voice

Speech or voice-based recognition systems identify a person based on their spoken words. The generation of human voice involves a combination of behavioral and physiological features. The physiological component of voice depends on the shape and size of vocal tracts, lips, nasal cavities, and mouth.

Speaker recognition is highly suitable for applications like tele-banking but it is quite sensitive to background noise and playback spoofing. Again, voice modality is primarily used in verification mode.

Figure I.7 Sample biometric traits: voice.

c) Gait

This is one of the newer technologies and is yet to be researched in more detail. Basically, gait is the peculiar way one walks and it is a complex spatio-temporal biometrics. It is not supposed to be very distinctive but can be used in some low security applications. Gait is a behavioral biometric and may not remain the same over a long period of time, due to change in body weight or serious brain damage.

Acquisition of gait is similar to acquiring a facial picture and may be an acceptable biometric. Since video sequence is used to measure several different movements, this method is computationally expensive [8].

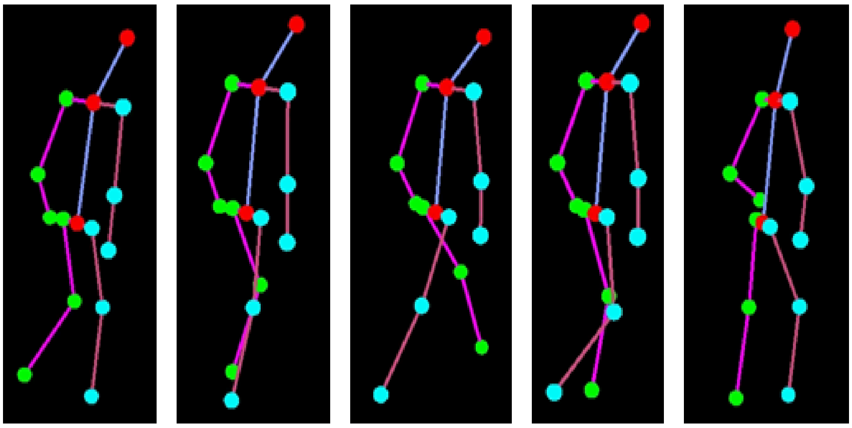


Figure I.8 Sample biometric traits: gait .

I.3.3 biological modalities

a) DNA: the DNA is an Acronym for Deoxyribonucleic Acid which is present in nucleus of every cell in human body and therefore a highly stable biometric identifier that represents physiological characteristic.

DNA is unique to each individual and may become more widely used as an identifier in the near future especially among immigrants as the technology to collect and sequence DNA becomes faster and less expensive, and as collection devices become smaller and more capable of use in the field.

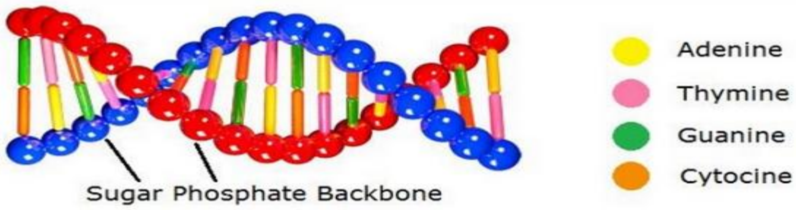


Figure I. 9 Sample biometric traits: DNA.

I.4 Function mode

A biometric system involves the following functional processes either in enrollment or tasting (verification or identification).

I.4.1 Enrollment mode

In this stage, the information captured from the subject by the sensing device is stored in a database for later comparison**.** It aims to create templates or references of each person to be used in the second mode (verification).

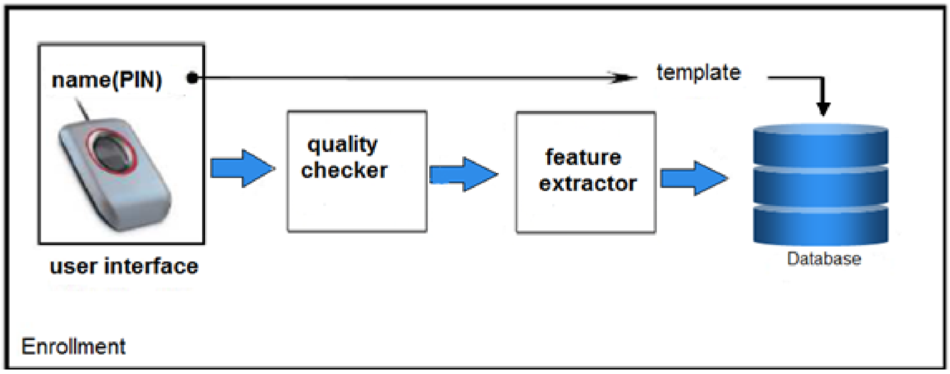


Figure I.10 Enrolement of persone in the biometric system.

I.4.2 verification mode

The system performs a one-to-one comparison of a captured biometric trait with a specific template stored in a biometric database in order to verify the individual is the person they claim to be[14]Positive recognition is a common use of verification mode, where the aim is to prevent multiple people from using same identity.

The pattern that is verified is only compared with the person's individual template. Similar to identification, it is checked whether the similarity between pattern and template is sufficient to provide access to the secured system or area [9].

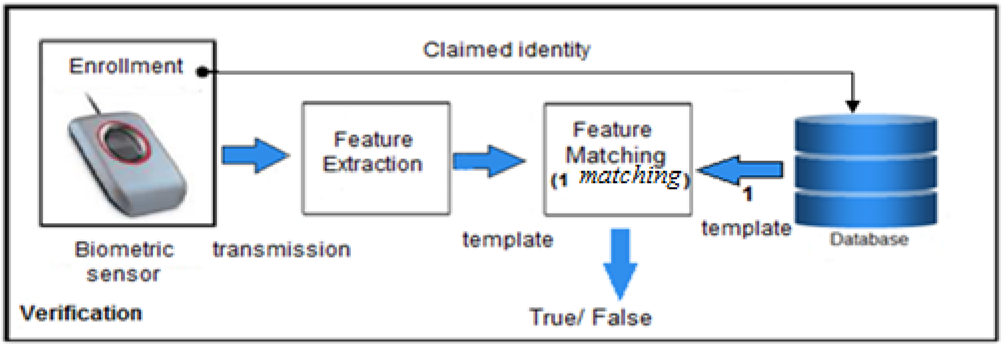


Figure I.11 Verification of person in the system biometric.

I.4.3 Identification (one to many matching)

A database of user models is searched for the most likely source of the biometric presentation. Thus, the biometric data is acquired, preprocessed, transformed into features, and post processed, before being matched with all the user models of interest. The user model that obtains the highest score with respect to the presentation is suggested to be the source of the presentation [10].

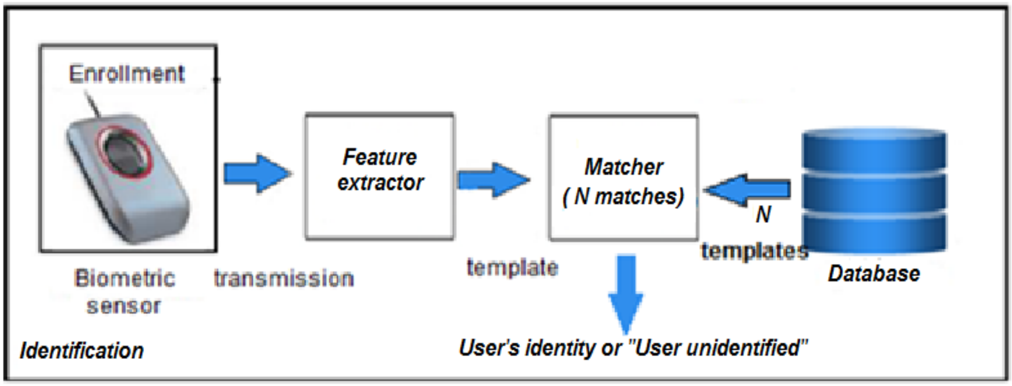


Figure I.12 Identification of person in the system biometric.

Depending on the application, we distingue:

- **Closed-set identification**: is where every input image has a corresponding match in the database.
- **Open-set identification:** (sometime referred to as a watch list application), the biometric system determines if the individual's biometric template matches a biometric template of someone in the database. The individual does not make an identity claim and in cases of covert identification, does not personally interact with the system what so ever.

I.5Performance evaluation of biometric system

The common question is always turn about the best biometric identification technique we can use. Naturally, there is no perfect performance of a system on biometric system by absolute condition, all depend on the precise nature of the application. There are four evaluation standards:

- **Intrusiveness**: the existence of a direct contact between the sensor used and the individual.
- **Reliability:** to criterion affects recognition of the user by the system.
- **Cost:** the cost of a biometric system would include the purchase price of the device, as well as administrative cost of setting up and maintaining the device, and the cost of the time spent by users in authenticating.

It might also include the cost of an alternative system for users who cannot be enrolled, and the cost of dealing with users who are falsely rejected by the system [11].

- **Effort:** deployed by the user when entering biometric measures.

I.6 Measuring the performance of a biometric system

System performance is a vague term and what it means depends much on what type of system it refers to. When talking about biometric systems performance, one usually means the probability that the system will accept authorized users and reject unauthorized users.

Biometric system usually has some security threshold setting that enables the system administrator to adjust the system to optimal performance. We can measure the performance of a biometric system by two indices:

I.6.1 False Acceptance Rate (FAR): This is defined as a percentage of impostors accepted by the biometric system. In identification biometric system the users are not making claims about their identity. Hence, it is necessary that this percentage is as small as possible so that the person not enrolled in the system must not be accepted by the system. Thus False Acceptance must be minimized in comparison to False Rejections.

The "False Acceptance Rate", which is the probability that a false identity claimed will be accepted, thus allowing fraud [12] is defined as:

$$FAR = \frac{\text{number of successful authentications by impostors}}{\text{number of attempts at authentication by impostors}} \quad (I.1)$$

I.6.2 False Rejection Rate (FRR): This is defined as a percentage of genuine users rejected by the biometric system.

Thus False Rejection is the instance of a security system failing to <u>verify</u> or <u>identify</u> an authorized person. A system's FRR typically is stated as the ratio of the number of false rejections divided by the number of identification attempts, the "false rejection rate", which is the probability that a true user identity claim will be falsely rejected, thus causing inconvenience [19], is defined as:

$$FRR = \frac{\text{number of failed attempts at authentication by authorized users}}{\text{number of attempts at authentication by authorized users}} \quad (I.2)$$

If we consider a threshold to confirm or not a proclaimed identity, two curves of FAR and FRR can be depicted as in the figure (I.13). Know as FAR and FRR distribution curves, they give us a view on the existence of an appropriate threshold where the biometric system provides relatively reduced FAR and FRR.

This case will occur if their distributions are separated or with narrow overlapping region

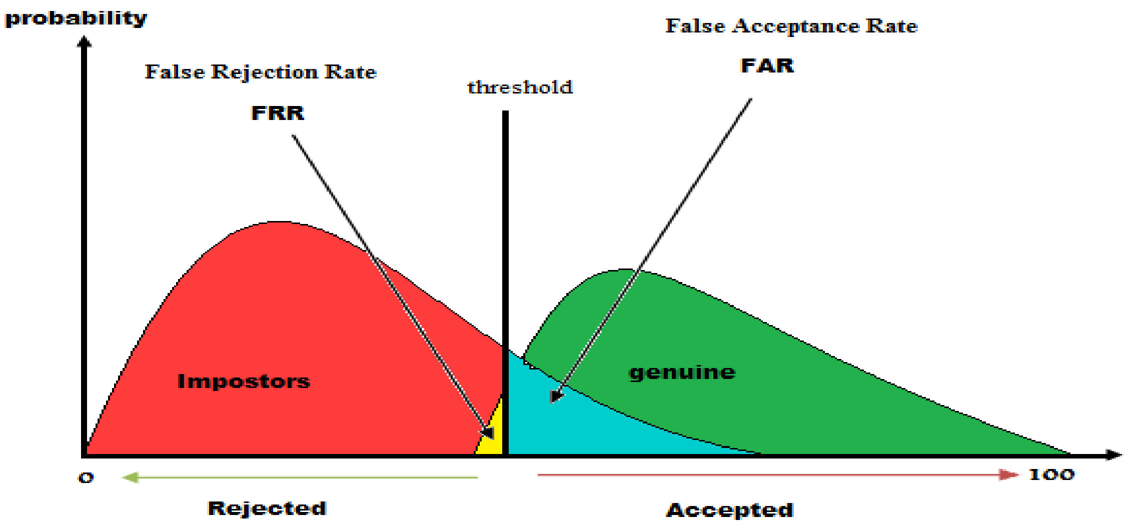


Figure I.14 FAR and FRR diagram.

I.6.3 Genuine Accept Rate (GAR): can be used as an alternative to FRR while reporting the performance of a biometric verification system. This is defined as a percentage of genuine users accepted by the system. It is given by:

GAR=1-FRR (I.3)

I.6.4 Equal Error Rate (EER): The EER of a system can be used to give a threshold independent performance measure. In theory this works fine, if the EER of the system is calculated using an infinite and representative test set, which of course is not possible under real world conditions.

To get comparable results it is therefore necessary that the EERs that are compared are calculated on the same test data using the same test protocol [9].

If we plot FAR and FFR on a graph, like on the one below, the EER is the point where the two curves intersect.

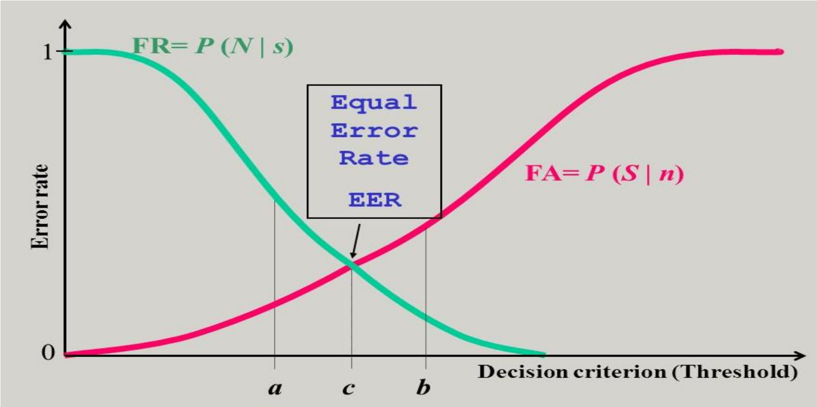


Figure I. 15 Equal Error Rate (EER).

I.6.5 Receiver Operating Characteristics (ROC)

The method most commonly used to assess the performance of a biometric system is the ROC curve. The aim is to plot a curve representing FRR according to the FAR. In order to plot this type of curve, we have to change the value of the decision threshold. For each value of the threshold, we calculate the associated FRR and FAR that we plot on the curve. The advantage of this method is that it gives a compact representation of the performance of a biometric system through a single curve allowing the comparison of different biometric systems.

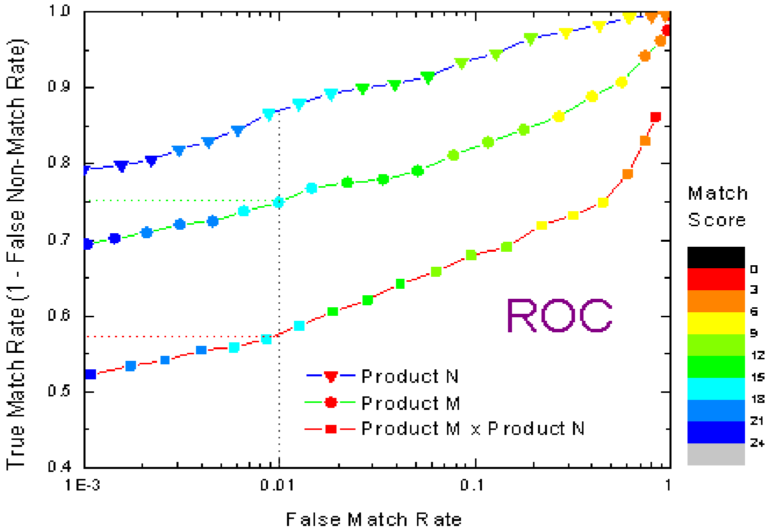


Figure I.16 Example ROC curves.

I.6.6 Cumulative Match Characteristic (CMC)

This is a method of showing measured accuracy performance of a biometric system operating in the closed-set identification task. Templates are compared and ranked based on their similarity.

The CMC shows how often the individual's template appears in the ranks, based on the match rate, a CMC compares the rank versus identification rate as illustrated below.

Figure I. 17 Example of CMC curve.

I.7Multimodal biometric systems

Depending on the biometric characteristic used, the quality and cost of the components of the biometric system and the algorithms, determines the quality of the reference biometric data.In the case of multimodalities, we will have two main choices is biometric system structure:

I.7.1 Unimodal biometric systems

Unimodal biometric systems perform person recognition based on a single source of biometric information. Such systems are often affected by the following problems:

a) **Noisy sensor data:** fingerprint images with a scar or a voice sample altered by cold are examples of noisy data. Noisy data could also result from defective or improperly maintained sensors or unfavorable ambient conditions [14].

b) **Non-universality:** The biometric system may not be able to acquire meaningful biometric data from a subset of users. A fingerprint biometric system, for example, may extract incorrect minutiae features from the fingerprints of certain individuals, due to the poor quality of the ridges

c) **Spoof attacks:** This type of attack is especially relevant when behavioral traits such as signature or voice are used. However, physical traits such as fingerprints are also susceptible to spoof attacks [14].

d) **Intra-class variations:** These variations are typically caused by a user who is incorrectly interacting with the sensor or when the characteristics of a sensor are modified during authentication [13].

e) **Inter-class similarities:** In a biometric system comprising of a large number of users, there may be inter-class similarities (overlap) in the feature space of multiple users [14].

I.7.2 Multimodal biometric systems

Some of the limitations imposed by unimodal biometric systems can be overcome by using multiple biometric modalities (such as face and fingerprint of a person or multiple fingers of a person). Such systems, known as multimodal biometric systems [15], are expected to be more reliable due to the presence of multiple, independent pieces of evidence [16].

These systems are also able to meet the stringent performance requirements imposed by various applications [17]. Multimodal biometric systems address the problem of non-universality, since multiple traits ensure sufficient population coverage.

I.7.3 Multi biometric system categories

A multi biometric system relies on the evidence presented by multiple sources of biometric information. Based on the nature of these sources, a multi biometric system can be classified into one of the following five categories [18]:

1) **Multi-sensor systems:** A single biometric modality is acquired by using a number of sensors. One example is multiple face cam-eras for creating a 3D input face or for combining the output scores of the different baseline face images.
2) **Multi-algorithm systems:** A single biometric input is processed with different feature extraction algorithms in order to create templates with different information content. One example is processing fingerprint images according to minutiae and texture-based representations.
3) **Multi-instance systems:** These systems use multiple instances of the same body trait and have also been referred to as multi-unit systems in the literature. For example, the left and right index fingers, or the left and right irises of an individual, may be used to verify an individual's identity [15, 16].
4) **Multi-sample systems:** A single sensor may be used to acquire multiple samples of the same biometric trait in order to account for the variations that can occur in the trait, or to obtain a more complete representation of the underlying trait. A face system, for example, may capture (and store) the frontal profile of a person's face along with the left and right profiles in order to account for variations in the facial pose.
5) **Multimodal systems:** Multimodal systems establish identity based on the evidence of multiple biometric traits. For example, some of the earliest multimodal biometric systems utilized face and voice features to establish the identity of an individual [8, 16, 19]. Physically uncorrelated traits (e.g., fingerprint and iris) are expected to result in better improvement in performance than correlated traits (e.g., voice and lip movement).

I.7.4 Fusion In Multimodal Biometric Systems

Multimodal biometric systems integrate information presented by multiple biometric indicators. The information can be consolidated at various levels, illustrates the three levels of fusion when combining two (or more) biometric systems. These are as follows:

Fusion at the feature extraction level

Either the data itself or the feature sets originating from multiple sensors/sources are fused.

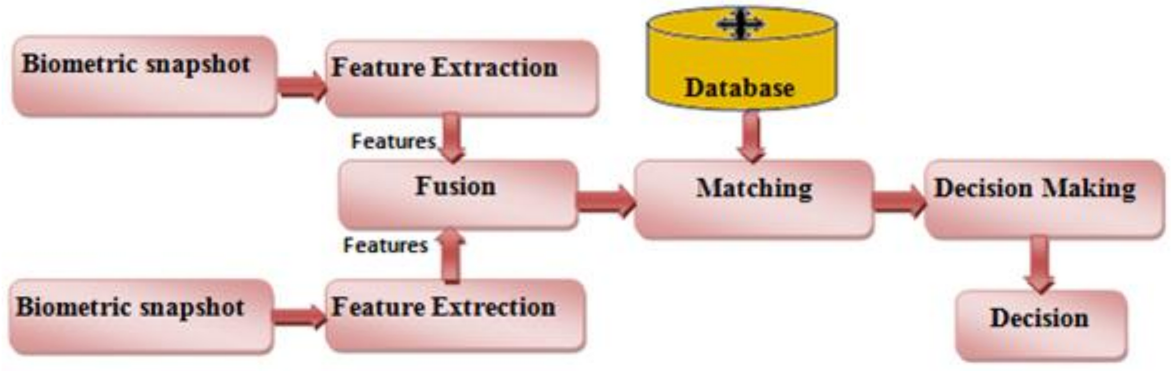


Figure I.18 Feature level Fusion .

Fusion at the matching score level

The scores generated by multiple classifiers pertaining to different modalities are combined.

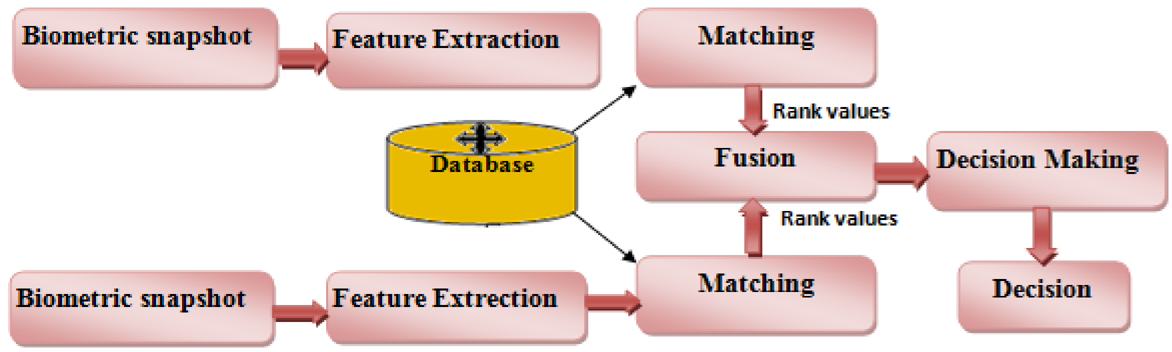


Figure I.19 Matching Score level Fusion.

Fusion at the decision level

The final outputs of multiple classifiers are consolidated via techniques such as majority voting.

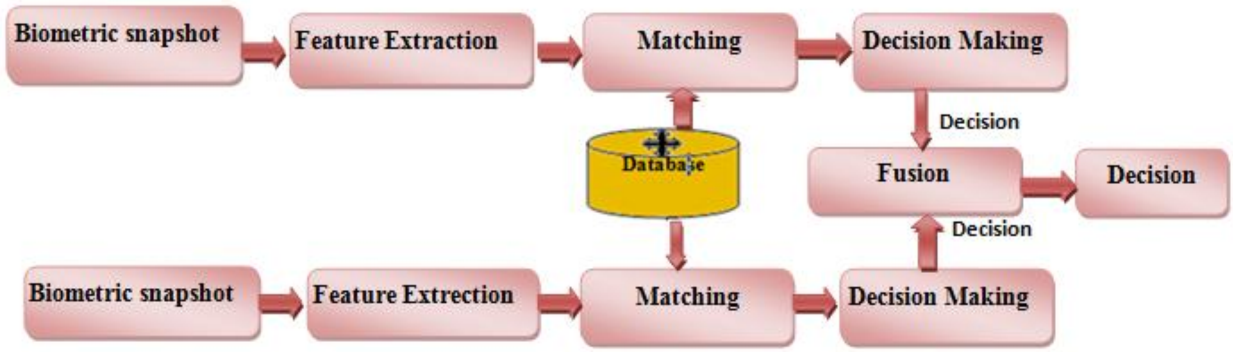


Figure I.20 decision level Fusion.

I.9 Conclusion

In this chapter, we presented some definitions and notions related to biometric systems. We had examined the construction of multimodal biometric system and the fusion operation. In the next chapter, we will focuse on the procedure to construct feature extraction model based on fuzzy logic system.

Chapter II

Feature extraction based on fuzzy modeling

II.1 Introduction

It is interesting that the human does not have sufficient capacity to deal with large amounts of numerical information and accurate data. However, he had an amazing versatility in making more complex decisions, totally unlike a computer which can do a lot more complex calculations in a split of second, while unable completely to do the most basic of human activities unless they are represented numerically.

The clearness of human superiority and the inability of the numerical systems pushed Dr. Lotfi A. Zadeh (University of Berkeley) to search and access to the fuzzy logic theory in 1965.This theory become one of the most successful techniques today to give birth to a sophisticated control system, the primary motivation to provide a mathematical representation of classes of objects that do not have precisely defined criteria of membership [20].

Fuzzy logic is much more general than traditional logical systems. The greater generality of fuzzy logic is needed to deal with complex problems in the realms of search, question-answering decision and control. Fuzzy logic provides a foundation for the development of new tools for dealing with natural languages and knowledge representation. This theory is very attractive, because it is a rigorous mathematical theory, adapted to the treatment of everything that is subjective or uncertain.

There are many fields of application of fuzzy logic for example the **Automotive Systems** (Vehicle environment control), **Consumer Electronic Goods** (Still and Video Cameras), **Domestic Goods** (Microwave Ovens), **Environment Control** (Air Conditioners/Dryers/Heaters).

In our study, we will use the theory of fuzzy logic in image’s modality characterization. Because the common information about fuzzy logic that everything is, or allowed to be partial, imprecise, linguistic and perception based. Unfortunately, he had a major problem represented in his large number of parameters which reflected in his inability to identify systematically the best parameters.

As a solution to this problem, we will propose a design method to find some optimal parameters. For that, we will use fuzzy system as modeling tool of biometric modality.

The rest of this chapter is organized as follows: first, we will develop the fuzzy logic systems and his main useful propriety followed by the modality image representation as nonlinear function. After that, we will examine the optimization problem and his resolution.

II.2 Fuzzy logic system

Fuzzy logic system belongs to the class of "knowledge-based systems" Aims to heuristic rules, in the form of a computer program. Fuzzy logic provides a mathematical formalism to achieve this goal. The fuzzy logic works on the levels of possibilities of input to achieve the definite output [21]. In fuzzy logic, the variables have values in the form of words or sentences of the language, such as "hot", "cold", "fast", "long" which known as **linguistic variable**. The importance of linguistic variable is embodied in the human succeeds in summarize the many information and analysis of complex systems and the issuance of the difficult decisions through the use of language and not to resort to quantitative and numerical variables. Next, we will give some definition related to fuzzy systems.

II.2.1 Membership functions

The membership function (MF) is used to determine the affiliation of any elements of fuzzy set, the basic condition of this function is to have a set of values between zero and one. Usually, the membership functions are denoted by the symbol $\mu(.)$ where the most common forms are:

a) **Singleton function:** A fuzzy set with a membership function that is unity at a one particular point and zero everywhere else as shown in Figure (II.1).

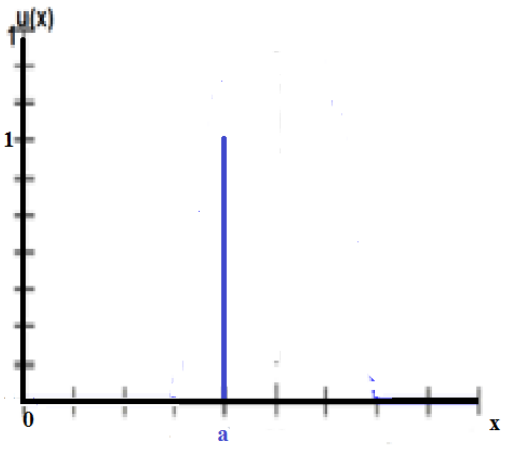


Figure II 1 singleton function.

b) **Gaussian function:** It is defined by two parameters $\{\sigma, m\}$:

$$\mu(x) = \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right) \quad \text{(II.1)}$$

The Gaussian function is illustrated in Figure (II.2)

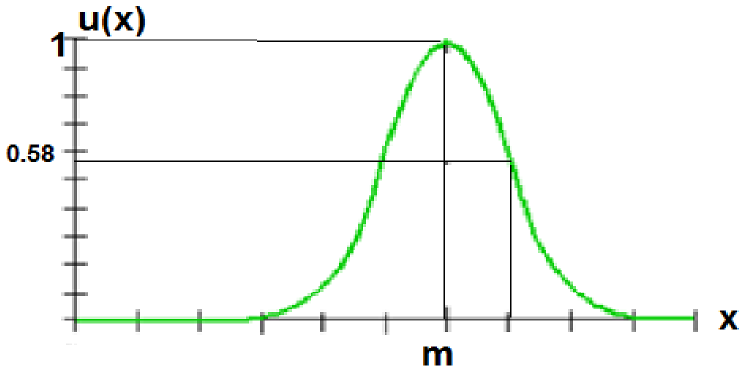


Figure II.2 Gaussian function.

c) **Triangular function***:* a triangular MF is specified by three parameters ***{a, b, c}*** as follows:

$$triangle(x; a, b, c) = \max\left(min\left(\frac{x-a}{b-a}, 1, \frac{c-x}{c-b}\right), 0\right) \quad \text{(II.2)}$$

Figure (II.3) depicts triangular function

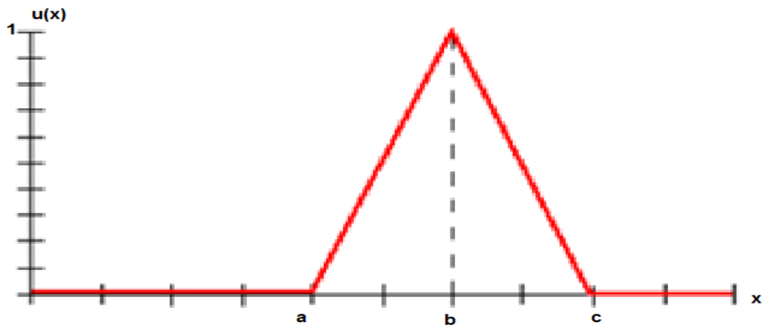


Figure II.*3* Triangular function

II.2.2 Logical operations

We need a number of logical operations to build a system based on fuzzy logic. Specifically, there are four basic operations to deal with uncertainty an variable which are:

a) **Intersection :**$\mu_{A\cap B}(x) = \mu(A \text{ AND } B) = min\{\mu_A(x), \mu_B(x)\}$

b) **Union**: $\mu_{A\cup B}(x) = \mu(A \text{ OR } B) = max\{\mu_A(x), \mu_B(x)\}$

c) **Complement** $\mu_{\bar{A}}(x) = \mu(\text{NOT A}) = 1 - \mu_A(x)$

d) Implication: It is a collection of laws or conditional phrases, called usually rules, consisting of : *"if","is", "and", "then ", "or "* . The first part of the rule is the condition and the second part is the Answer of the condition or output.

II.2.3 Fuzzy system modules

A FLS consists of four main parts: *fuzzifier*, *rules*, *inferenceengine*, and *defuzzifier*. These components and the general architecture of a FLS is shown in Figure (II.4).

a) Fuzzification:

The process of transforming input numerical value into fuzzy value like probability function. In this manner, the input can be treated in next stage. Habitually, if the user has trust in incoming measure or the input it is sufficient to make fuzzification by singleton function.

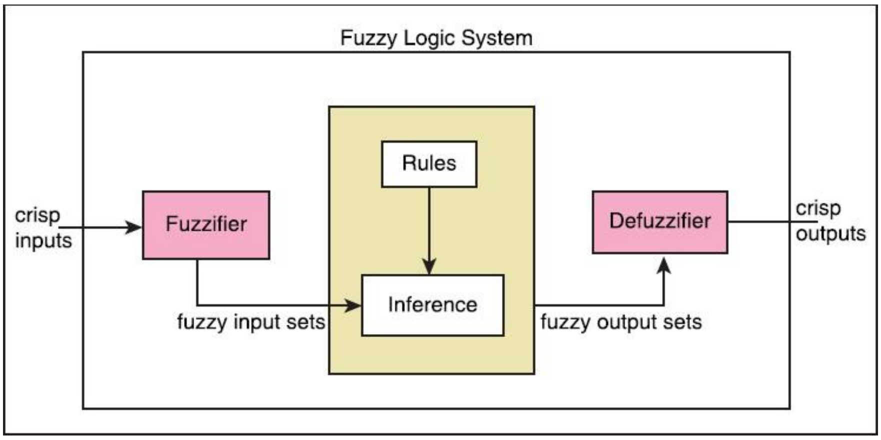


Figure II.4 Structure of fuzzy logic system.

b) Knowledge Base: The central part of fuzzy systems is the collection of decision rules. They are formulated in the form of ''if….then …'' phrases. These rules are obtained from experts and historical information about the system to model. As example, by reading the position (***x, y***) of pixel in image we can predict the correspondent gray level.

The equivalent rule can be written as follows:

$$\textbf{if } x \textbf{ is } A_{1i} \textbf{ and } y \textbf{ is } A_{2i} \textbf{ then } I \textbf{ is } A_{3i} \qquad \text{(II.3)}$$

Where A_{ji} is the nameof the membership function of the associated variable (***x*** or ***y***) in the i^{th} rule.

c) The inference: It simulates the human reasoning process by making fuzzy inference on the inputs and ***IF-THEN*** rules and to make instantaneous output from the actual fuzzified input.

To the output, it is necessary to attribute operators for each term. We mean by "terms" the following words: "is", "*and* ", "*or*", "*if-then*". The associated operators can be chosen from various norm functions. As example we give the following case:

''is'' : singleton fuzzification with product;

''And'': Product function;

''Or'': sum;

''If-then'': product function;

d) Defuzzification: His role is to transform the degrees of belonging to the fuzzy subsets of the output into numerical quantity. This is the inverse transformation of the fuzzification module.

II .2.4 Type of Fuzzy Inference System

The most two known types of fuzzy inference system (FIS) are:

a) Mamdani-type FIS:

Mamdani-type inference expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification,this type has the following general form for two entries

$$R_k : if\ x\ is\ A_{1k}\ and\ y\ is\ A_{2k}\ Then\ \ I\ is\ A_{3k} \qquad (II.4)$$

Here, the consequence is related to membership function of the output variable.

b) Sugeno-type FIS:

This model is similar to Mamdani model, constructed based on *"If ... Then ..."* rules. Even, the premise always expressed linguistically, the consequence uses numerical variables rather than linguistic ones.

Consequently, the result can be expressed, for example, as a constant, a polynomial or, more generally, as a function depending on the input variables.

In general, a Takagi-Sugeno (TS) model is based on a collection of rules, for example, in the case of two input variables, the R_k rule is expressed as:

$$R_k : \text{If } x \text{ is } A_{1k} \text{ and } y \text{ is } A_{2k} \text{ then } f_l(x, y) = b_{0k} + b_{1k}x + b_{2k}y; \qquad k=1..m \qquad \text{(II.5)}$$

Where R_k denotes the k^{th} rule of the model, and $\boldsymbol{m}$ is the number of rules contained in the rule base. The most fundamental difference between Mamdani-type FIS and Sugeno-type FIS is the way the crisp output is generated from the fuzzy inputs. In more general case, the output of the fuzzy system is given by:

$$I(x_1, \dots, x_n) = \sum_{l=1}^{m} \frac{\prod_{i=1}^{n} \mu A_{il}(x_i) f_l(x_1, \dots, x_n)}{\sum_{l=1}^{m} \prod_{i=1}^{n} \mu A_{il}(xi)} \qquad \text{(II.6)}$$

If $f_l(.)$ are zero order polynomials functions (constants), the fuzzy output will be expressed as:

$$I(x_1, \dots, x_n) = \xi^T \theta \qquad \text{(II.7)}$$

Where : the activation vector $\xi^T = [\xi_1 \dots \xi_m]$ is defined as :

$$\xi_l = \frac{\prod_{i=1}^{n} \mu A_{il}(x_i)}{\sum_{l=1}^{m} \prod_{i=1}^{n} \mu A_{il}(xi)} \; l = 1..m \qquad \text{(II.8)}$$

And the parameter vector θ is given by:

$$\theta^T = [b_{01} \dots b_{0m}] \qquad \text{(II.9)}$$

So, the fuzzy system output is separated into two parts. The activation vector ξ^T combines known functions and the vector parameters θ^T that enclose unknown parameters. An important advantage is the linearity of the output versus the parameter vector which will be useful in eventual analysis as will be done in next sections. In the remaining part of this chapter, we will only consider TS-FIS.

From the previous equation, a fuzzy system produces an output with nonlinear behavior versus the inputs. So, fuzzy systems can be considered as candidate system to model complex nonlinear functions or dynamics. Unfortunately, the fuzzy system theory doesn’t give us enough information on how to design the unknown parameters.

II .2.5 Universal approximation

In the literature, we find an important property that makes fuzzy systems useful in modeling and identification problems. In several research works [22][23], authors show the ability of such systems to approximate some classes of nonlinear functions with bounded errors. This property is well known as “Universal approximation”. In these works, the authors prove the capacity of fuzzy systems to approximate any nonlinear smooth functions that only if we use a fuzzy system with sufficient number of rules.

In this case, an unknown nonlinear function $I^{*}(\boldsymbol{x})$ with the input vector $\boldsymbol{x} \in \boldsymbol{R}^{\boldsymbol{n}}$can be approximated by a fuzzy model$\hat{I}(\boldsymbol{x})$ such that the error $\delta(\boldsymbol{x}) = \left|I^{*}(\boldsymbol{x}) - \hat{I}(\boldsymbol{x})\right|$ will be bounded.

In next sections, we will exploit these advantageous proprieties of fuzzy systems to look for an appropriate representation of modality image. Before that, let us introduce the image associated function to be used later.

II .3 Image modeling by TS-FIS

The image as a simple knowledge known as a physical likeness or representation of a person, animal, or thing, photographed, painted, sculptured, or otherwise made visible. The digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels, each pixel of a digital image has a digital number represents the amount of radiation recorded by the sensor for this area.

One of the images type's is grayscale which representing the two-dimensional matrix size [$\mathbf{X}\times\mathbf{Y}$] of luminance. It falls within the field (0 to 1), where 0 represents black color and the white is represented by 1. The values between them represent gray level. The picture we will show bellow make this kind of image clear.

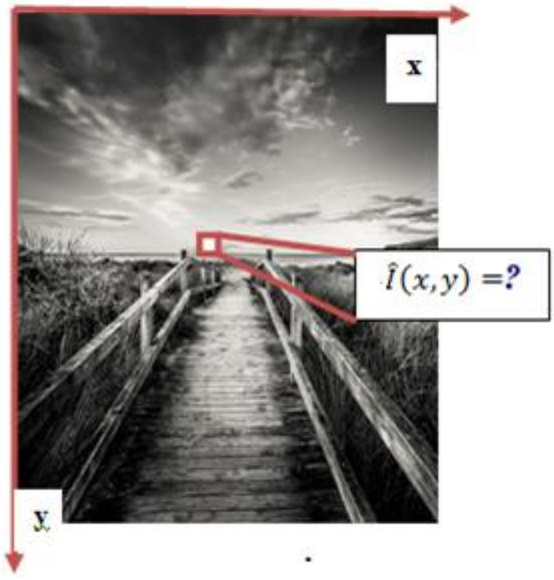


Figure II 5 Grayscale image.

It is clear that pixel gray level change versus its position, so we propose to define the image associated function (denoted as$I^*(x,y)$) as the gray level variation versus the two coordinates of pixel. From previous discussion, it is possible to approximate such function by TS-FIS model.

In order to reproduce the gray level with sufficient accuracy and we can write:

$$I^*(x,y) = \xi^T(x,y).\theta \qquad \text{(II.10)}$$

To define the TS-FIS, we have to choose an appropriate number and distribution of membership functions of $\boldsymbol{x}$ and $\boldsymbol{y}$ variables, so the activation vector will be entirely known. The remainder problem will be the identification of the parameter vector that produces acceptable errors. The obtained parameters will constitute the feature vector of the modality.

II.4 Quadratic problem formulation

Parameter vector synthesizes must ensure minimization of the approximation error. Quadratic formulation is the most known ones in the field of error minimization. The cost function is defined as the sum of error squares throughout the entire image. We define this cost function as:

$$J(\theta) = \sum_i \sum_j \left|I(x_i, y_j) - I^*(x_i, y_j)\right|^2 = \sum_i \sum_j \left|I(x_i, y_j) - \xi^T(x_i, y_j).\theta\right|^2 \qquad \text{(II.11)}$$

Where $I(x_i, y_j)$is gray level of image pixel with coordinates (x_i, y_j). Our objective is to find an optimal vector $\hat{\theta}$ such that:

$$\hat{\theta} = \text{argmin}_\theta\big(J(\theta)\big) = \text{argmin}_\theta\,(\textstyle\sum_i \sum_j \big|I(x_i, y_j) - \xi^T(x_i, y_j).\,\theta\big|^2 \qquad \text{(II.12)}$$

Firstly, we will try to rewrite the cost function expression in a matrix quadratic form. The equation (II.11) can be written as:

$$J(\theta) = \sum_i \sum_j (\, I^2(x_i, y_j) - 2.\,I(x_i, y_j)\xi^T(x_i, y_j).\,\theta + \theta^T \xi \;\; (x_i, y_j).\,\xi^T(x_i, y_j).\,\theta\,)$$

In compact form:

$$J(\theta) = \frac{1}{2}\theta^T A\,\theta + B^T\,\theta + c \qquad \text{(II.13)}$$

Where the matrix A and the vectors B and the scalar c are given as follows:

$$A = 2\sum_i \sum_j \xi(x_i, y_j).\,\xi^T(x_i, y_j)$$

$$B = -\sum_i \sum_j 2.\,I(x_i, y_j)\xi^T(x_i, y_j)$$

$$c = \sum_i \sum_j I^2(x_i, y_j)$$

It is to note that the matrix Adepend only on the chosen membership functions. The vectors **B** and **C**are function of the membership functions and the pixel gray level.

In this compact quadratic form, the unknown parameter vector appears separated from the know functions. So, we are able to select one of the several algorithms that resolve quadratic problems which are known as optimization methods. In this work, we will apply the gradient method.

II.5 Quadratic problem optimization with gradient method

Optimization is the act of obtaining the best result under given circumstances, it can be defined as the process of finding the conditions that give the maximum or minimum of a function. The optimum seeking methods are also known as mathematical programming techniques and are generally studied as a part of operation research.

This later is a branch of mathematics concerned with the application of scientific methods and techniques to decision making problems and with establishing the best or optimal solutions.

The optimisation has problems like all the mathemathics method, some of optimisation problems for example : single variable or multivariable, linear or nonlinear,sum of squares, quadratic, smooth or non-smooth. We will focus on quadratic problems witch defined as nonlinear programming problem with a quadratic objective function and linear constraints. It is usually formulated as bollows :

$$J(\theta) = \frac{1}{2}\theta^T A\,\theta + B^T\,\theta + c$$

Usually, the objective function is arranged such that the vector $\boldsymbol{B}$contains all of the (singly-differentiated) linear terms and $\boldsymbol{A}$ contains all of the (twice-differentiated) quadratic terms. Put more simply, $\boldsymbol{A}$ is the Hessian matrix of the objective function $J(\theta)$and $\boldsymbol{B}$ is its gradient. By convention, any constants contained in the objective function are left out of the general formulation [24].The one-half in front of the quadratic term is included to remove the coefficient (2) that results from taking the derivative of a second-order polynomial.

In the literature, the gradient method is well known in quadratic problem resolution. This method proposes an iterative research methodology where the solution is enhanced from step to the next one. It is based in the fact that the minimum of a convex function is situated in the opposite sense of the function gradient. So the actual presumed solution is adjusted, at each step, by the calculated gradient vector with factor (α). Figure (II.6) illustrate an example of the solution convergence to the optimum.

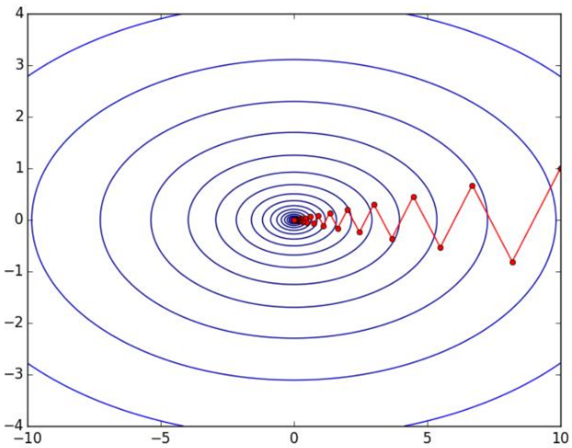


Figure II 6 Optimization of a quadratic function

The gradient method algorithm can be summarized as follows:

Gradient method algorithm

Begin

Initialization: $n = 0$, θ_0, N_{max} , α

Loop when $n < N_{max}$

Compute the gradient $\nabla J(\theta_n) = \left(\frac{\partial J}{\partial \theta_{1n}} \frac{\partial J}{\partial \theta_{2n}} \dots \frac{\partial J}{\partial \theta_{mn}}\right)^T$

Update the solution as $\theta_{n+1} = \theta_n - \alpha . \nabla J(\theta_n)$

Update $n = n + 1$

End of loop

The optimal solution is θ_{Nmax}

End

The corresponding organigram is depicted in the following figure.

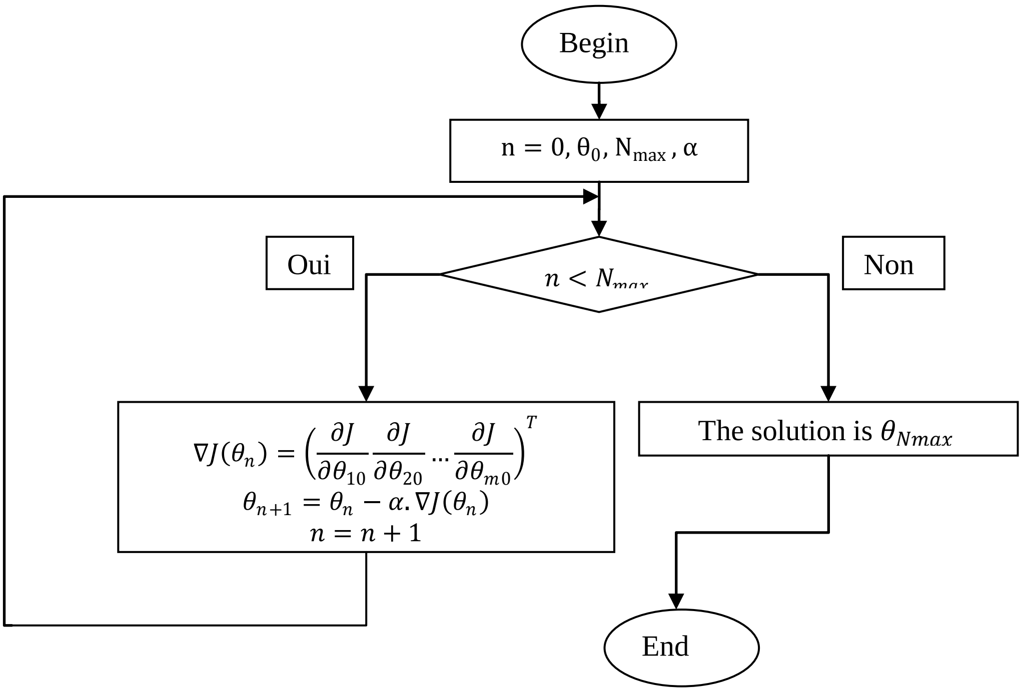


Figure II.7 Organigram of Gradient method.

The gradient method strategy is based on the adjustment of solution on the base of computed gradient of the cost function (J).

The convergence to the optimal solution depends on the choice of both initial solution value and the weighting factor (α). The last one can affect considerably the convergence since it determines the amount of added correction to the actual solution. Relatively, high values produce more oscillations, however low values will provide slow convergence.

The most important advantages of this method are the reduced execution time and the simplicity of the used expressions. These expressions are simplified tanks to both the selected function cost structure and particularly to the fuzzy Sugeno model output expression witch appear affine in unknown parameters vector.

II.6 Conclusion

In this chapter, we had formulated the identification of biometric images as a quadratic problem optimization. The gradient method was presented as simple algorithm to find the best solution that minimizes the approximation error of the biometric image by Sugeno fuzzy model. We suggest considering the optimal vector, determined by the gradient method, as the feature vector of biometric modality.

Chapter III

Experimental results and discussion

III.1 Introduction

A successful biometric system depends on the accuracy with which it works. The degree of accuracy is measured with biometric parameters, this chapter addresses the various parameters used in the analysis and measurement of a Biometric system, this chapter also presents experimental results of a palm biometric identification system with a PolyU database, the performance is measured with a variable threshold.

III.2 Palm recognition

The palmprint is another unique biometric characteristic fit for use in biometric systems. Palm is used as reliable, cost effective, easily acquired person identification modality. The inner palm surface consists of many unique features such as principal lines, ridges, wrinkles, and delta points, as shown in figure **III.1**.

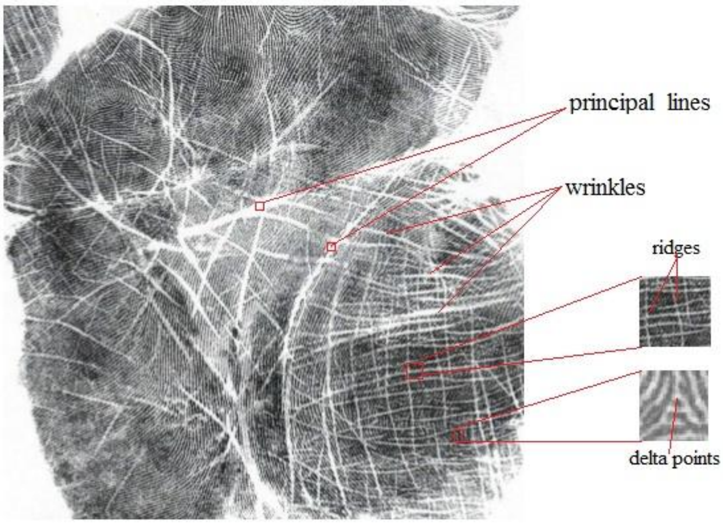


Figure III.1: The three principal lines on a typical palm.

Figure **III.2** shows the structure of the designed multispectral palmprint image acquisition device. It is composed of a charge-coupled device (CCD) camera, lens, an analog-to-digital (A/D) converter, a multispectral light source, and a light controller. A monochromatic CCD is placed at the bottom of the device.

The A/D converter connects the CCD and the computer. The light controller is used to control the multispectral light [25].

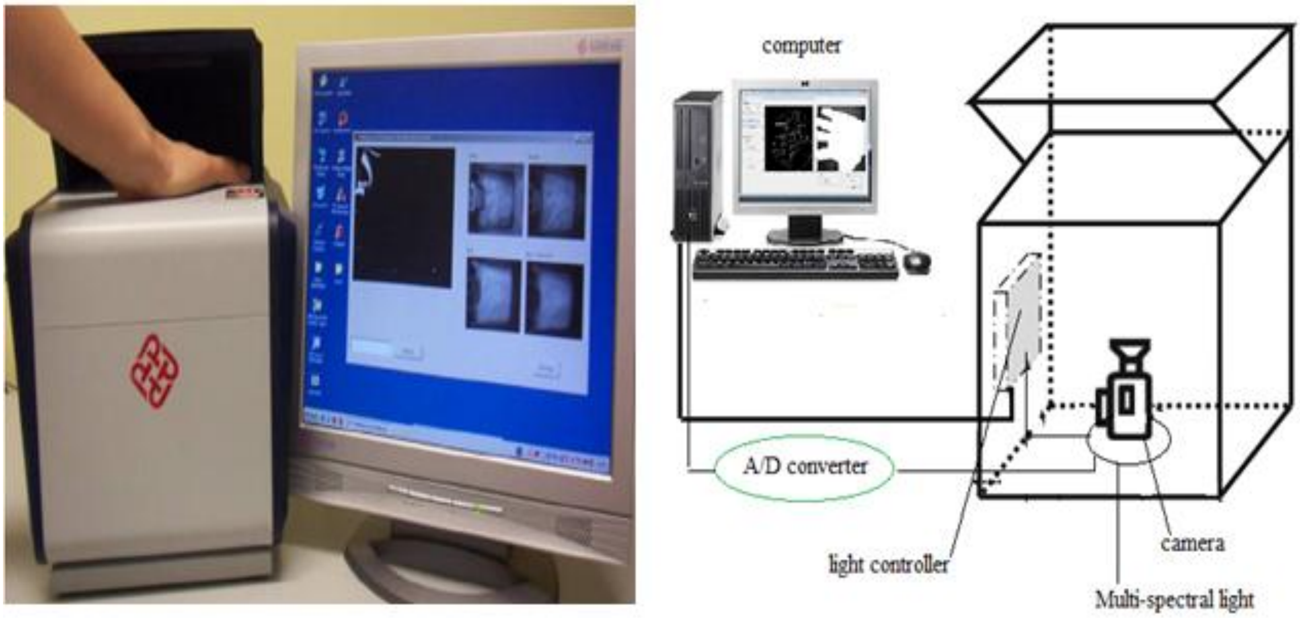


Figure III.2 Prototype of multispectral palmprint system and his structure.

III.3 Proposed biometric System

A biometric system has four stages of processing. In the sensor stag, a biometric image is captured and enrolled as an input to the system which is used for verification or identification. In the feature extraction stage, the feature of the enrolled data is extracted and stored as a feature set and is further processed for verification or identification. In the Matching stage, the features extracted are matched with the stored features set in the database and the degree of similarity is measured as a matching score, by setting a threshold. In the Decision stage, the users claim is either accepted to be genuine or rejected as an imposter depending on the matching score.

In This chapter will propose a multimodal biometric system with focusing on the multi simple system he based on the modality of palmprint as type of recognition which stored in PolyU database that we going to deal with as we mentioned before,

The feature vectors obtained will be enter a comparison process to determine the user whose palmprint photograph was taken.

This comparison is to be made against user templates, which will be calculated depending on the comparison algorithm used. Therefore, we will use **the Euclidean distance method (MED)**[26] [27], which known as most common technique of all. It performs its measurements with the following equation:

$$\mathbf{D}(\boldsymbol{\theta_i},\boldsymbol{\theta_{mi}}) = \sqrt{\frac{1}{M}\sum_{i=1}^{M}(\boldsymbol{\theta_i} - \boldsymbol{\theta_{mi}})^2} \qquad \text{(III.1)}$$

- M: being the dimension of the feature vector.
- $\boldsymbol{\theta_i}$: the i^{th} component of the sample feature vector,
- $\boldsymbol{\theta_{mi}}$: the i^{th} component of the template feature vector.

The template vector dimension is, therefore, the same as one of the sample vectors. In order to calculate such a template, a set of photographs is taken and the mean of the resulting set of feature vectors is taken as the user's template.

In the case of multimodal biometric system, we suggest a score level fusion. Hence, the vectors extraction from the cloosen modalities are compared to the recorded models in the Database to compute the corres ponding scores. Finnaly, the best score of the two modalities will be teken as the candidate score.

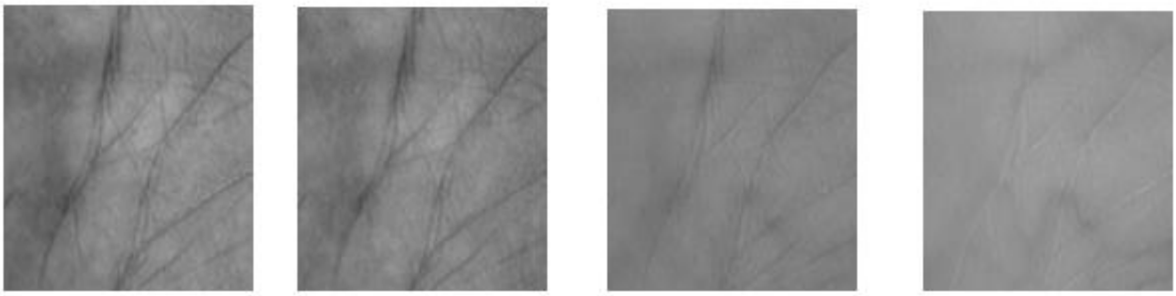
III.4 Results and discussion

III.4.1 Database of palmprint images

The palmprint images that we used in our experiment belongs to **ployU**(database), where The Biometric Research Centre (UGC/CRC) at The Hong Kong Polytechnic University has developed a real time multispectral palmprint capture device which can capture palmprint images under blue, green, red and near-infrared (NIR) illuminations, and has used it to construct a large-scale multispectral palmprint database.

Multispectral palmprint images were collected from 250 volunteers, including 195 males and 55 females. The age distribution is from 20 to 60 years old. Collecting samples is achieved in two separate sessions. In each session, the subject was asked to provide 6 images for each palm. Therefore, 24 images of each illumination from 2 palms were collected from each subject. In total, the database contains 6,000 images from 500 different palms for one illumination. The average time interval between the first and the second sessions was about 9 days.

An example of the collected images is shown in figure III.4**.**



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

Figure III.3 Examples of PolyU database: a) blue, b) Green, c) Red, d) NIR

III.4.2 Database separation

To evaluate the performance of palm print recognition system, we used **PolyU**with 500 persons each individual has 12 image divided in tow section the first one has 3 images used in enrollment phase, after that we used the last 9 images in the test phase.

a) Learning images: at this step the first one, 5^{th}and9^{th} are processed.

b) Test images: the last nine images,($2^{ed}3^{ed},4^{th},6^{th},7^{th},8^{th},10^{th},11^{th},12^{th}$) of each individual used in the various stages of test.

III.4.3 Adaptation of parameters

III.4.3.1 Work Environment

In this section, we will present the hardware and software environments:

1) Hardware environments :

To develop this application, we use a machine, configured as follows:

- ❖ Laptop : Acer-PC
- ❖ Memory (RAM) : 4.00 Go.
- ❖ Processor: Intel (R) Core (TM) I3-2328M CPU @ 2.20 GHz.
- ❖ System Type : Operating System 32 bits

2) Software environnements

For the development of this application, we used the following software tools: Matlab 7.7.0 (R2014a).

III.4.3.2 Working Protocol

The choice of the best parameters (**Niter**: number of iteration, **Nfa**: number of membership function) has an impact on the recognition (verification and identification) rate of the system. Therefore, we will choose the best of them after the adaptation process, and apply them in the algorithm which will be applied in the unimodal system. In order to enhance the performance of unimodal system we will use the multimodal system for best results.

We have two curves in the unimodal cases, the first is ROC that Plotting FRR vs. FAR, this curve is used in the case of open set mode. The second curve named as CMC curve. A better system is one that is closest to the top left corner of CMC.

The following table presents the**ROR** and **RPR**(closed-set identification mode) for the different iteration number in the case of**Nfa=20** in palmprint database(Near-Infrared NIR):

Table III.1 results of the ROR and RPR.

Data base		Number of iteration	ROR	RPR
500 Personne	NIR	5	99.13	340
		10	99.22	341
		15	99.2	350
		20	99.2	350
		25	99.2	352
		30	99.58	484
		35	99.58	484
		40	99.18	351

The figure that we will show below represent a graph of the identification rate in terms of iteration number (Niter).

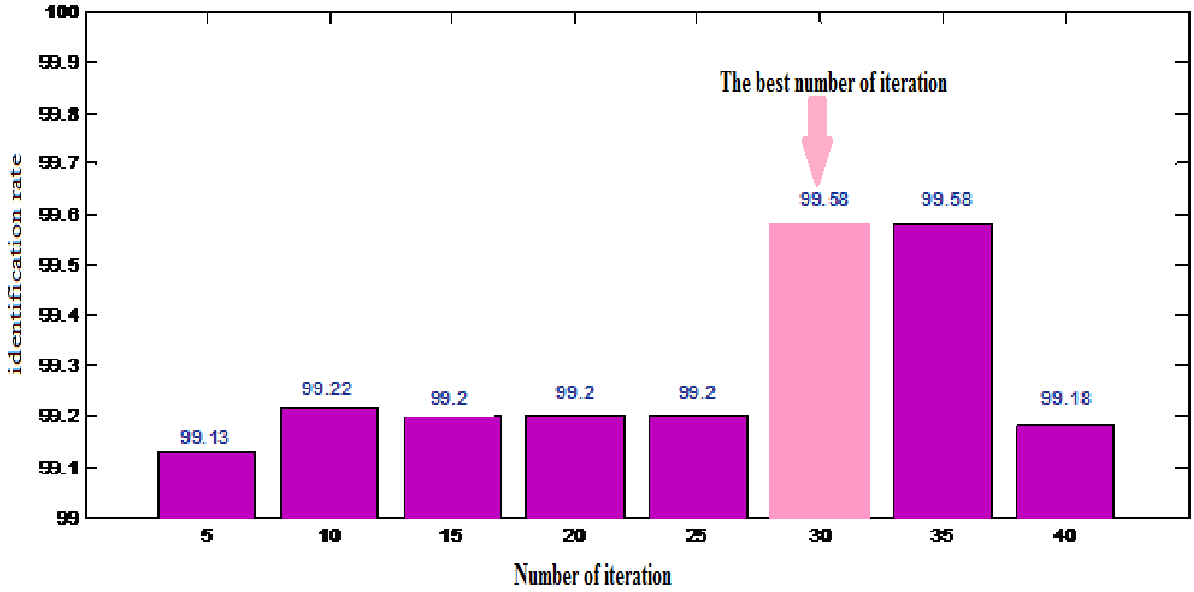


Figure III.4 bar graph showing the identification rate in terms of iteration number (Niter).

From this table (**III.1**) and Figure **(III.4),** we can observe that the closed set identification accuracy becomes very high at certain classifiers for NIR band, where it reaches 99.58% twice for respectively in the cases of number of iteration 30 and 35.

In this result we can remark that the values less than 30 of iteration number which is (5, 10, 15, 20, and 25) give us unacceptable results compared with the results obtained in 30 and 35.From the **Table III.2**, we conclude that the best result gives by: **iteration number =30,** after we got all the results we compared them to each other to choose the best among them which is the iteration number (**Niter=30**), It was chosen because it has the least time of execution compare with the case of number of iteration = 35.But compared to other number of iteration, it gives best result.

In the other hand, if we continue to change the values of iteration number, we will cause the loss of best result and we will have returned to the worst results. After selecting the best result of iteration number, we fixed this value and we began to change the values of membership function numbers, hopefully that we get better results.

The following table represent the results of ROR and RPR for the different values of membership function numbers (Nfa)in the case of **iteration number =30**.

Table III.3 Results of ROR and RPR for different values of Nfa (Niter=30).

Nfa	Clesed_set identification	
	ROR	RPR
3	0.7333	498
4	0.7556	498
5	0.6667	498
6	1.956	498
7	2.911	498
8	4.489	497
9	8.933	494
10	7.156	495
11	7.711	495
12	8.4	495
13	8.578	494
14	99.47	336
15	99.36	348
16	99.38	346
17	99.33	352
18	99.29	348
19	99.18	349
20	99.18	352

After we have determined the best result of iteration number, we will fix it (Niter) after that we changed the value of membership function number (Nfa), until we get the best value for Nfa , which allows us to keep the minimum possible error rate.

Depending on the table's results (**Table III.4),** which includes the results of ROR and RPR (Closed-set identification mode).

- In the case of Nfa confined between 3 and 13, we observe from table (III.5 **)** that the values of Nfa from 3 to 13, which give the results of ROR (0.7333%, 0.7556%, 0.6667%, 1.956 %, 2.911%, 4.489%, 8.933%, 7.156 %, 7.711%, 8.4%, 8.578%) respectively, that the values of ROR are increasing but in small percentages, obviously, this values will not help us to get the perfect results.
- In the case of Nfa = 14, we find that the value of ROR = 99. 47%, it is a perfect result so far.
- As we note that the values enclosed between 15 and 20 give the values of ROR (99.36%, 99.38%, 99.33%, 99.29%, 99.18%, 99.18%), respectively, in continuous decline.

Obviously and based on the table's results, we conclude that the best membership function number which contributes with the iteration number to give as the best results of the lowest error value **(iteration number =30** and **number of membership function = 14)**.

III.4.4 Unimodal results

We will apply the best of iteration number (Niter) and membership function number (Nfa) which was tested in the case of near-infrared (NIR) and retest them in Blue, Green, Red images.

The results of the Blue, Green, Red and near-infrared (NIR) bands test are represented in the following table using

Table III.6 Unimodal results of EER, T_0, ROR and RPR for Nfa =14 Niter=30,

using palm print images (Blue, Green, Red and NIR).

Bands	**Open set identification**		**Close set identification**	
	EER	**T_0(%)**	**ROR**	**RPR**
Bleu	**6.653×10^{-5}**	**0.137**	**99.71**	**490**
Red	**9.98×10^{-4}**	**0.142**	**97.76**	**257**
Green	**1.66×10^{-2}**	**0.1352**	**84.18**	**480**
NIR	**1.996×10^{-4}**	**0.1489**	**99.47**	**336**

In the open set the Blue band gives the best **EER** over the other bands (Red, Blue and Green), and the result of **ROR** and **RPR** are very plausible.

The following curves **(Figure III.5),** represent **FRR** versus **FAR** graph and **CMC** curve **(Figure III.6)**:

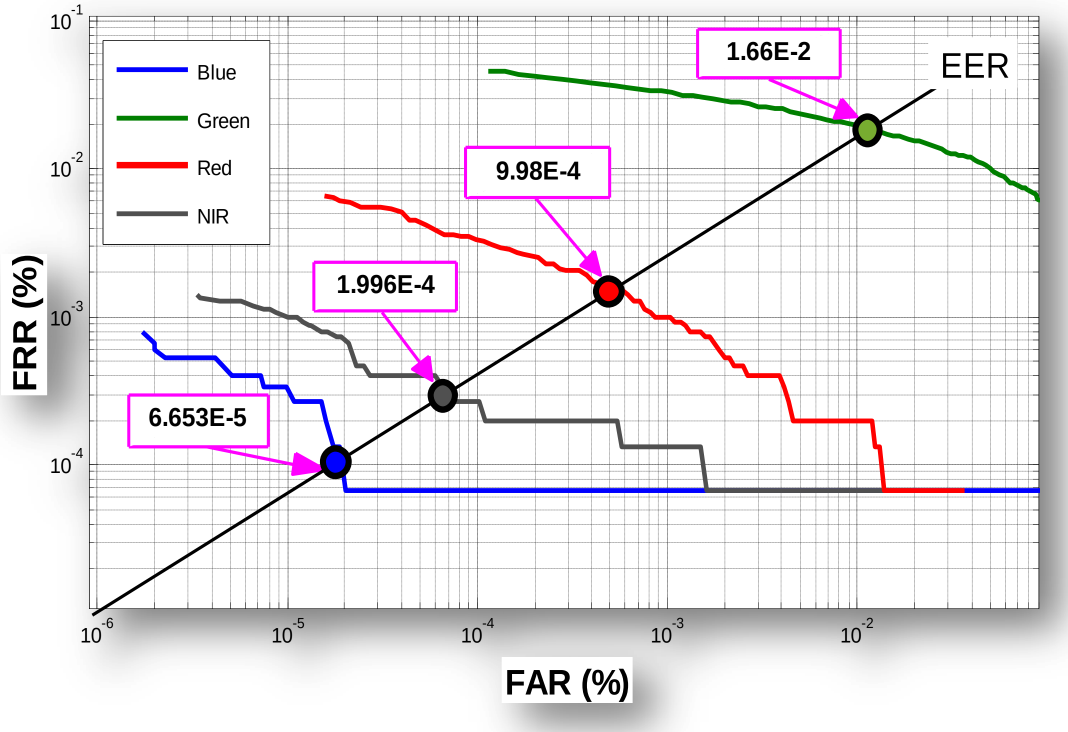


Figure III.5 ROC curves (FRR against FAR).

This curve **(Figure III.5**) shows the equality error (EER) of each band as a function of the false rejection rate (FRR) and the false acceptance rate (FAR).

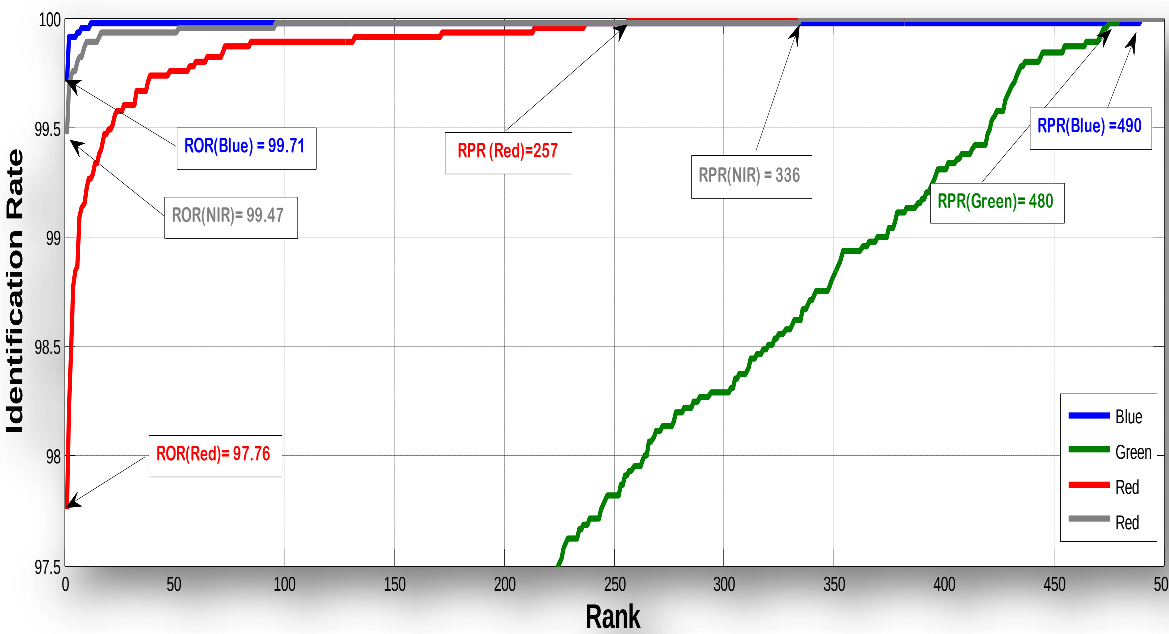


Figure III.6 CMCcurve .

III.4.4.1 Discussion

From the table (**III.3**) and figure**(III.6),** we can give the following points:

- we remarked that compared with the best case in the unimodal system, the best results of ROR produces an accuracy of 99. 71%with RPR=490

- in the case of Green band at given a upper limit EER equal to 1.66× $\mathbf{10^{-2}}$ at $\boldsymbol{T_0}$=0.1352, because the Green band as given not sufficient and poor information compared with another bands
- Other bands are given acceptable values compared to green, but the blue remains the best result compared with all bands (NIR and Blue and Red and Green)
- We can observe in the ROC curves that the EER values for Blue, Red, Green, and NIR are 6.653× $\mathbf{10^{-5}}$ % , 9.98× $\mathbf{10^{-4}}$%, $\mathbf{1.66} \times \mathbf{10^{-2}}$ %, $\mathbf{1.996} \times \mathbf{10^{-4}}$ respectively, so, the best result is Blue.

III.4.5 Multi modal results

The growing interest in the use of multiple modalities in biometrics is due to its potential capabilities for overcoming certain important limitations of unimodal systems, researchers believe that the use of multimodal biometrics will provide a more reliable and robust system. However, the goal of this experiment was to investigate the systems performance when we fuse information from some spectral bands. In fact, at such a case the system works as a kind of multimodal system with a single biometric (palmprint) but multiple spectral bands. Therefore, the information presented by different bands (Blue, Green, Red, and NIR) is fused to make the system efficient.

Four possible levels of fusion can be used for integrating data from two or more modalities [28], these levels are the sensor level, the feature level, the matching score level and the decision level, in our study, the fusion at matching score level is used. Currently, this level appears to be the most useful fusion level because of its good performance and simplicity and there is sufficient information content and it is easy to access and combine the matching scores.

in order to see the performance of the system, we have evaluated different fusions of color bands and Table (III.4) summarizes the equal error rates for these experiments

Following table (**III.7)**Present the unimodal results which have been amplified by the multimodal system where we fused **Bleu** with **Red**, **Blue** with **Red** with **Green**, **NIR** with **Blue**, **NIR** with **Red** and **NIR** with **Green**, **Blue** with **Red** with **Green** with **NIR.**

Table III.8 Multimodal results .

Fusion	Open set identification		Closed set identification	
	EER	$T_0(\%)$	ROR	RPR
Bleu+Red	1.331×10^{-4}	0.176	99.77	411
Blue+Red+Green	1.331×10^{-4}	0.1493	98.75	358
NIR+Blue	6.653×10^{-5}	0.1944	99.91	259
NIR+Red	1.342×10^{-4}	0.147	99.555	168
NIR+Green	4.125×10^{-3}	0.1523	95.088	442
Blue+Red+Green+NIR	1.996×10^{-4}	0.1417	99.48	241

In this case, the two following figures **III.7**and**III.8** show multimodal **ROC** and **CMC** curves**.**

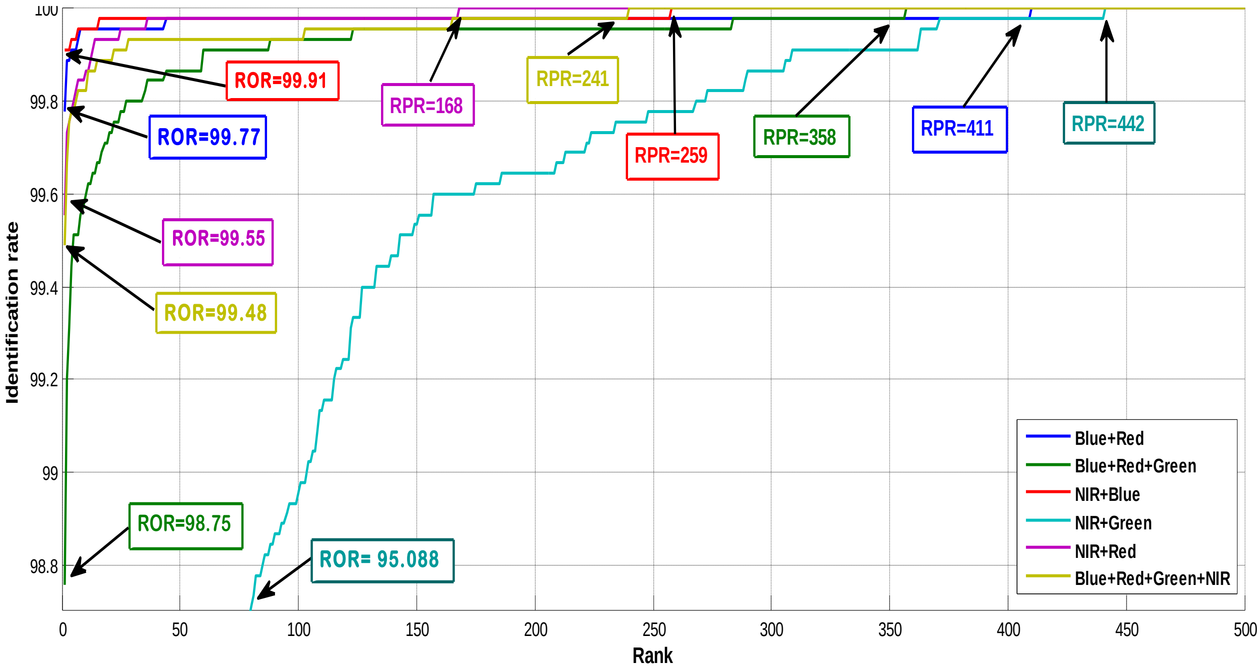


Figure III.7 Multimodal CMC curve .

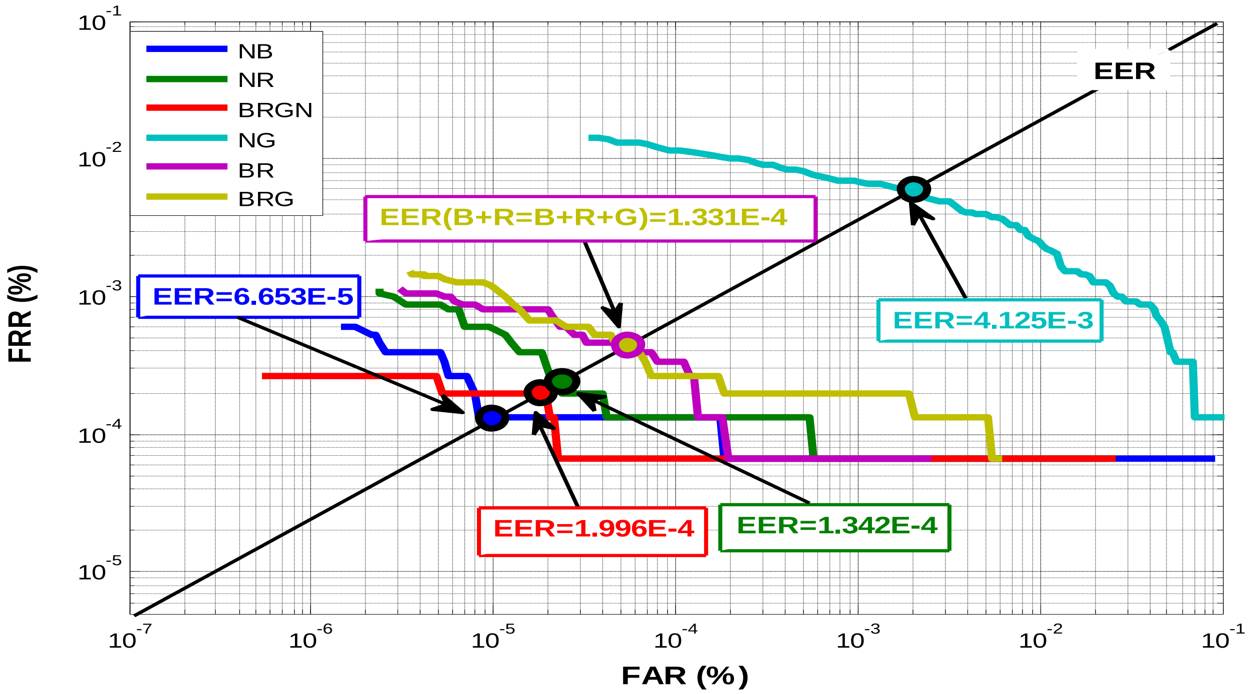


Figure III.8 ROC curves (FRR against FAR).

III.4.5.1 Discussion

At this stage (the multi-modal system), each sub-system computes its own matching score and these individual scores are finally combined into a total score (fusion at the matching score level), which is used by the decision module. Based on this matching score a decision about whether to accept or reject a user is made, the precision of the multimodal system is better than that of the unimodal system.

From Table (**III.9)**, we can observe the advantages of using the R, G, B, N fusion:

- For example, a fusion of (NIR+Blue) has the minimum EER equal to 6.653×10^{-5}% at T_0= 0.1944and this is the pest results.
- In the cases of open-set identification it is clear that the first and second combination (Blue+Red) and (Blue+Red+Green) are very similar where EER equal to 1.331×10^{-4} % in both cases In the cases of two bands, for example, a fusion of (**Bleu+Red**) give an acceptable value of EER equal to 1.331×10^{-4}% at T_0 = 0.176 compared to the case of the fusion of three , Combination of (NIR+Green) gives an upper limit EER equal to

  4.125×10^{-3} at T_0=0.1523 caused by the Green .
- Combination of (Blue+Red+Green+NIR) give an acceptable results where EER equal to 1.996×10^{-4} at T_0=0.1417%.

- The use of four bands can be help full to improve the results compared with the use of three bands when we fused (Blue+ Green+Red+NIR) it give acceptable results where EER is equal to 1.996$\times 10^{-4}$ at T_0=0.1417%, thanks to the three bands (Blue,Red andNIR) that carries enough information

- According to thetable **III.10**and the figure **III.7**, the ROR values for all the fusion of spectral bands(Blue+Red), (Blue+Red+Green), (NIR+Blue), (NIR+Red), and (NIR+Green), (Blue+Red+Green+NIR) are: 99.77 %, 99.75%, 99.91%, 99.555%,95.088%, 99.48% , respectively, we NotedNIR+Blue given best result of ROR
- From the **Table III.11** and **Figure III.7**the RPR values for all the fusion of spectral bands (Blue+Red, Blue+Red+Green, NIR+Blue, NIR+Red , and NIR+Green, Blue+Red+Green+NIR) are: 411, 358, 259, 168, 442, 241.

From the results obtained we can said that the precision of the multimodal system is better than that of the unimodal system.

III.5 Conclusion

In this chapter, to confirm the validity and the efficiency of the gradient method extraction algorithm, we applied it to PolyU database. The obtained results in monomodal case show relatively high performance in term of EER and RPR Cases. These results were enhanced by the adaption of multimodal biometric system where more information were combined by fusion at matching level.

General Conclusion

GENERAL CONCLUSION

Biometrics which use of human physiological characteristics for identifying an individual is now a widespread method of identification and authentication. Biometric identification is a technology which uses several image processing techniques, Palmprint recognition has been verified investigated over 10 years. During this period, many different problems related to palmprint recognition have been addressed.

The objective of our work is to improve the performance of biometric identification and verification using the Palmprint, for this we have proposed the use of fuzzy logic in principle, Unfortunately, he had a major problem represented in his large number of parameters which reflected in his inability to identify systematically the best parameters.

As a solution to this problem, we proposed a design method to find some optimal parameters.

For that, we used fuzzy system as modeling tool of biometric modality.

For that we had formulated the identification of biometric images as a quadratic problem optimization. The gradient method was presented as simple algorithm to find the best solution that minimizes the error approximation of the biometric image by Sugeno fuzzy mode.

Finally, the results obtained are interesting, we got a very close recognition rate of 100 % which makes the system reliable.

Our future work is focused on evaluating performance in both phases (verification and identification) using a large database and integration of other biometric features to achieve system performance with high accuracy

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