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Memory

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Domain: Science and Technology Specialty: automatic and system

Submitted by:

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Theme

Biometric modality characteristics extraction using fuzzy model

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Dedication

To my father to my mother

To my brothers and sister To my family

In memory of my grandparents To all my friends automatic group

To all my teachers and teachers: from primary to higher

To all those who have contributed to the development of science in general and

Electronics in particular

Tidjani Mohamed laid

Dedication

To my dear mother

To my brother

In memory of my father and all who we lost in this journey

To all my relatives in the TOUIDJINE and AIMEUR families, and more particularly

To all my dear friends and colleagues at the University of Ouargla

To each and everyone who taught me a letter, who guided me through this path

Touidjine Mohamed Aymen

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

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

يعتمد العمل المقدم في هذه الرسالة على مفهوم نظام القياسات الحيوية ومكوناته. يعتبر تحلل نظام القياسات الحيوية إلى: نظام أحادي الوسائط ونظام متعدد الوسائط. ويستند تحقيق وتقييم هذا الأخير إلى صفقة الاندماج.

يهدف هذا العمل إلى استخراج متجه الميزات من البصمة الحيوية باستخدام نموذج غامض. يتم إنشاء الأخير بحيث تكون صورة البصمة قريبة بدرجة كافية من صورة افتراضية تم إنشاؤها بواسطة النظام الضبابي. لهذا ، تتم صياغة مشكلة التحسين ثم حلها بطريقة التدرج اللوني.

يُظهر التطبيق الموجود على قاعدة بيانات صورة الكف أداءً جيدًا جدًا في الوضع الأحادي والوسائط المتعددة ، في كلا الوضعين: تحديد الهوية والتحقق.

الكلمات المفتاحية :
النظام البيومتري –الانصهارات- النظام المتعدد الوسائط- النظام الضبابي- خوارزمية الأشد انحدارا- الصورة البيومترية - مقرب عالمي - دالة تربيعية.

Résumé

Le travail présenté dans ce mémoire se base sur le concept du système biométrique et de ses composants. Il considère la décomposition du système biométriques en : système monomodale et système multimodale. La réalisation et l'évaluation de ce dernier se base sur l'opération de fusion.

Ce travail vise à extraite de vecteur caractéristique de l'empreinte biométrique en utilisant un modèle flou. Ce dernier est créé de manière à ce que l'image de l'empreinte soit suffisamment proche d'une image virtuelle crée par le système flou. Pour cela, un problème d'optimisation est formulé ensuite résolu par la méthode du gradient.

L'application sur une base de donnée d'image de paume de la main, montre des très bonnes performances en mono et multimodale et cela dans les deux modes : identification et vérification.

Mots clés : biométrique – enrôlement - multimodal - logique floue - gradient- fonction quadratique- approximation universelle- modèle.

Abstract

The work presented in this memory is based on the concept of biometric system and its components. It consider the decomposition of biometric systems on mono and multi modal systems. The realisation and evaluation of later one is based on fusion operation.

This works aims to extract feature vector of the biometric modality using fuzzy model. This last is created in such manner that a virtual fuzzy image will be sufficiently close to the original biometric image. So, an optimisation problem is formulated and resolved using enhanced gradient method.

The application on images database of palmprint show a very good performance in either mono and mutli modal system in both identification and verification modes.

Key words: biometric - multimodal - fuzzy logic - universal approximator - recognition - palm print - quadratic function.

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General Introduction

The need for civil protection, on the one hand, and the fight against fraud and crime, on the other hand, place at the center a security system for many areas such as transport, banking, public services, etc. The common denominator is to offer simple, practical and reliable means to verify or identify the identity of any person, without the assistance of another person.

This identity can be proved by different methods: first, by presenting a badge or an identity card, this is what one has, then, by dialing the password. Pass, it is a question, in this case, of what we know. Finally, anyone can prove their identity, for example through their fingerprints or the iris of their eye. This identification is based on the characteristics of the person himself, we then speak of biometrics.

The extraction of features, or the extraction of the vector of observations, is an essential step in a biometric recognition system. A vector of characteristics (vector of observations) is used to represent the discriminating characteristics of the image of the modality of the person with, generally, a reduced dimension compared to the image. This vector can be modeled with a model in order to have a better identification.

Fuzzy logic is a technique widely used in the field of control of industrial systems and processes; our contribution is to use this technique for the modeling of the vector of biometric characteristics [1].

For this, our thesis entitled "biometric identification system based on a fuzzy model" is the tool to achieve the objective of this contribution; this memory is organized as follows:

In the first chapter, we will introduce some definitions of biometrics and different biometric modalities, and then we detail the palm modality for the identification of a person.

In the second chapter, we will discussed the basic and theoretical notions of fuzzy logic, the different fuzzy models, the learning and gradient methods.

In the third chapter, we will develop our biometric system with the proposed optimisation algorithm followed by the obtained results and discussion.

Finally, we will terminate this work by a conclusion.

chapter I

Introduction to Biometric Systems

I.1 Introduction:

Due to the escalating level of security breaches and transactions frauds, the need for highly secure identification and personal verification technologies becomes essential. Using a human body for recognition is developed as for its convenience and adds more security to authenticate.

This type of recognition uses the human's own characteristics like facial expressions, human emotions, intentions, and behavior to verify the human's own identity.

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

I.2 Definition of biometrics:

The term "biometrics" is derived from two Greek words "bio (life)" and "metric (to measure)".

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 morphologic features (fingerprints, 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 meet the following properties:

- **Universality:** Every individual accessing the application should possess the trait. **Uniqueness:** The given trait should be sufficiently different across members of the population.

- **Permanence:** The biometric trait of an individual should be sufficiently invariant over time with respect to a given matching algorithm. A trait that changes significantly is not a useful biometric.
- **Measurability:** It should be possible to acquire and digitize the biometric trait using suitable devices that do not unduly inconvenience the individual. Furthermore, the acquired raw data should be amenable to processing to extract representative features.
- **Acceptability:** Individuals in the target population that will utilize the application should be willing to present their biometric trait to the system.
- **Circumvention:** The ease with which a biometric trait can be imitated using artifacts for example, fake fingers in the case of physical traits and mimicry in the case of behavioral traits should conform to the security needs of the application.

I.3 The main types of biometric technologies:

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

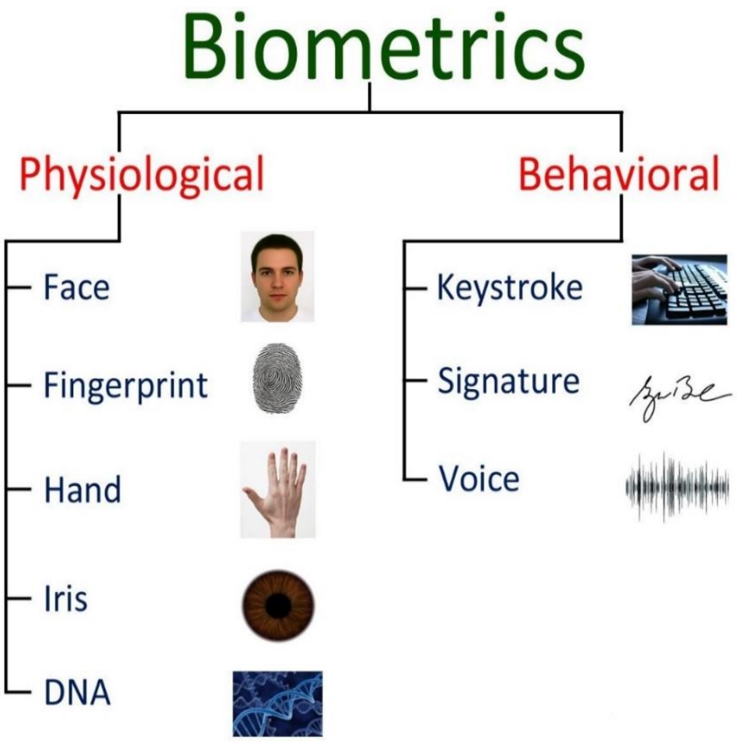


Figure I-1 types of biometric technologies

I.3.1 Morphologic modalities:

a) Fingerprint:

The fingerprint system is a popular biometric system and actively researched area in biometric technologies. The fact that every person has a unique stamp of fingerprints helped the system to become “A much needed system”. It is a low cost system as compared with other recognition systems. Fingerprints consist of series of ridges and furrows on the surface of the finger and patterns such as swirls, loops or aches surrounded the core, which make them distinctly different for each person.

Ridges are the outer layer segments of the finger while valleys are the lower layer segments. Both are identified by irregularities called as minutiae, which become the basis of finger scanning technologies.

Figure I-2 Example of finger print biometric

b) Face Recognition:

A face recognition system is one type of biometric that can identify or verify a person from a digital image by comparing and analyzing patterns.

Present facial recognition systems work with face prints and these systems can recognize 80 nodal points on a human face. Nodal points are nothing but endpoints used to measure variables on a person’s face, which includes the length and width of the nose, cheekbone shape, and eye socket depth.

c) IRIS Recognition:

Iris is a biometric feature, found to be reliable and accurate for authentication process comparative to other biometric features available today [2]. The iris patterns in the left and right eyes are different, and so scan be used quickly for both identification and verification applications because of its large number of degrees of freedom. Iris is like a diaphragm between the pupil and the sclera and its function is to control the amount of light entering through the pupil.

Figure I-3 Sample biometric traits: Iris

d) Palm-print:

The palm-print is one of the most reliable means in personal identification because of its stability and uniqueness. In fact, palm-prints have been taken as a human identifier for a long time. Using hand features as a base for identity verification is relatively user-friendly and convenient.

The palm is the inner surface of the hand between the wrist and the fingers. The main patterns in a palm-print can be generalized as principal lines, wrinkles and creases.

Figure I-4 Sample biometric traits: hand geometry

e) 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.

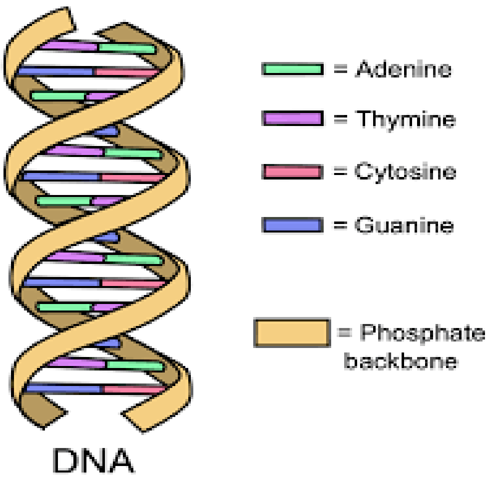


Figure I-5 Sample biometric traits: DNA.

I.3.2 Behavioral modalities:

a) Signature:

Biometric signature an authentication method that uses the dynamics of a person's handwritten signature. The pen pressure and duration of the signing process, which is done with a stylus on a touchscreen or digital-based pen tablet, is recorded as an algorithm that is compared against future signatures.

Figure I-6 Sample biometric traits: signature.

b) Voice:

Voice biometrics identifies specific speakers rather than the words they say. Each of our voices has distinguishing characteristics determined by our anatomy and behavioral speech patterns. The shape and size of our mouths and throats, as well as our language, pitch and speaking patterns (i.e., fast-talking versus slow talking) all shape our voices.

Voice biometrics maps a speaker's unique characteristics and then uses the map for later identification. A user provides one or more audio samples, which the system analyzes to create a unique voiceprint for the speaker. Whenever the user calls in, the software compares the speaker's voiceprint to the voiceprint on file.

Figure I-7 Sample biometric traits: voice.

c) Gait:

The simplest definition of gait states that it is the manner and style of walking. It can be more sophisticatedly defined as the coordinated cyclic combination of movements that result in locomotion. This definition can be equally applicable to any form of activity that is repetitive and coordinated to cause motion of the living being originating it. Gait can vary from walking, running, climbing and descending the stairs, swimming, hopping and so on.

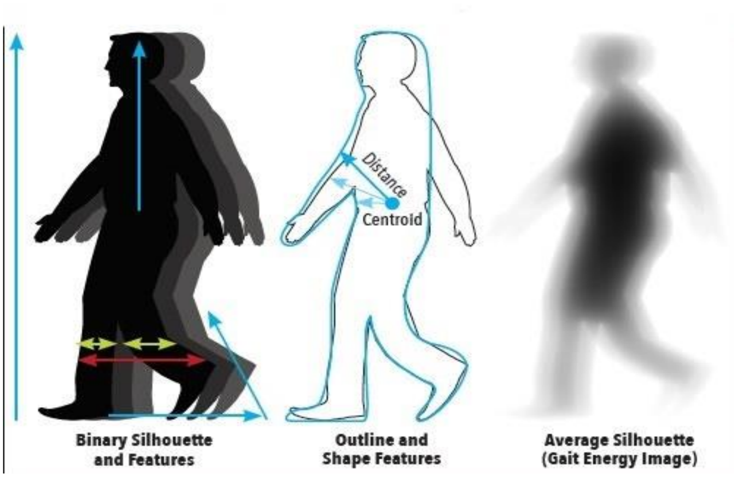


Figure I-8 Sample biometric traits: gait .

I.4 Function Mode of Biometric System:

A biometric system involves the following functional processes either in enrollment or testing (verification or identification) as shown in figure (I-9):

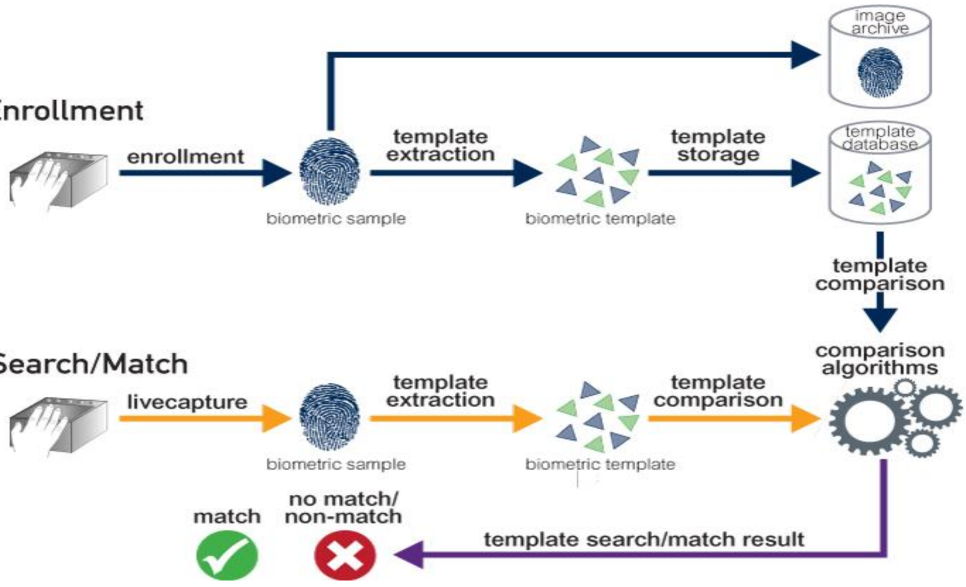


Figure I-9 Function Mode of Biometric System.

I.4.1 Enrollment Phase:

Enrollment consists of biometric measurements that are captured from a given subject, relevant information from the raw measurement is gleaned by the feature extractor, and (feature, person) information is stored in a database. This process is illustrated in figure (I-10).

Additionally, some form of ID for the subject may be generated for the subject (along with the visual/machine representation of the biometrics).

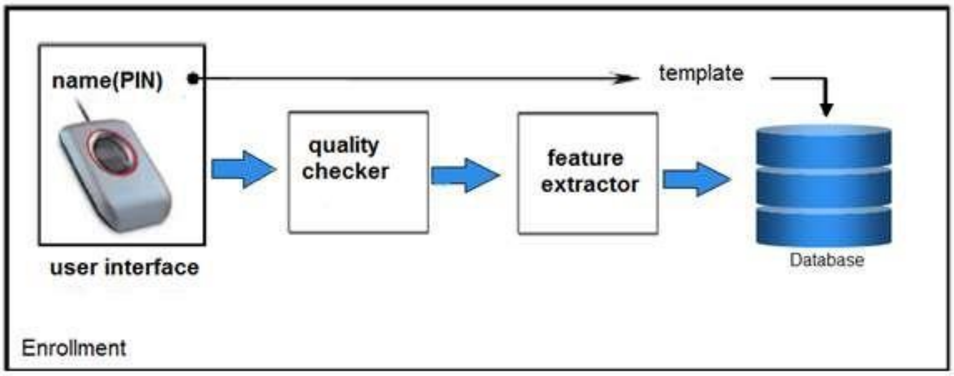


Figure I-10 Enrolement of persone in the biometric system.

I.4.2 Verification Phase:

This mode consists in verifying whether a person is who he or she claims to be. It is called a one to one matching process, as the system has to complete a comparison between the person‘s biometric feature vector and only one chosen template stored in the database. The processing is shown in figure (I-11).

Such a mode is applied when the goal is to secure and restrict specific accesses with obviously cooperative users.

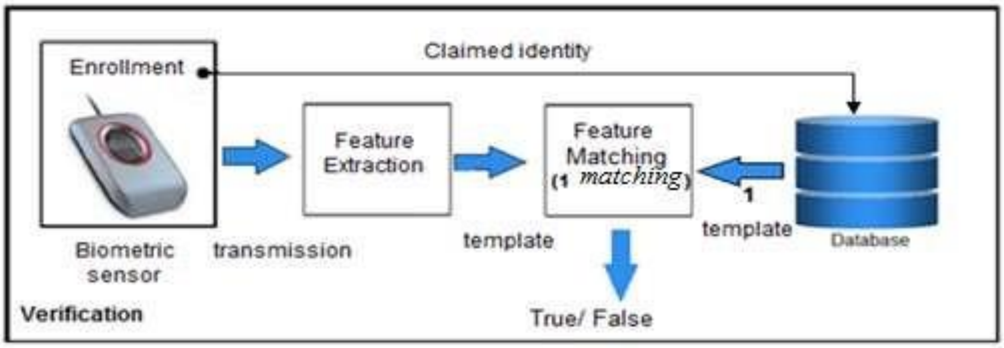


Figure I-11 Verification of person in the system biometric.

I.4.3 Identification Phase:

This mode consists in selecting the correct identity of an unknown person from a database of registered identities, see figure (I-12). It is called ―one to many matching process, because the system is asked to complete a comparison between the person‘s biometrics and all the biometric templates stored in the database. Two modes are possible, positive and negative identification. The positive identification tends to determine if a given person is really in a specific database. A negative identification determines if a given person is not in a watch list database.

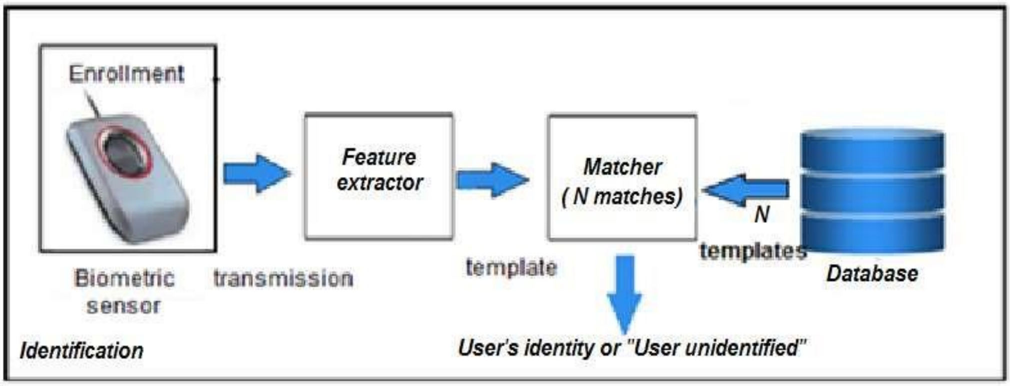


Figure I-12 Identification of person in the system biometric.

I.5 Principal Modules of a biometric System:

A biometric system is designed using the following four main modules:

- **Sensor module:** which captures the biometric data of an individual. An example is a fingerprint sensor that images the ridge and valley structure of a user's finger.
- **Feature extraction module:** in which the acquired biometric data is processed to extract a set of salient or discriminatory features.
- **Matcher module:** in which the features extracted during recognition are compared against the stored templates to generate matching scores. For example, in the matching module of a fingerprint-based biometric system, the number of matching minutiae between the input and the template fingerprint images is determined and a matching score is reported. The matcher module also encapsulates a decision making module, in which a user's claimed identity is confirmed (verification) or a user's identity is established (identification) based on the matching score [3].
- **System database module:** which is used by the biometric system to store the biometric templates of the enrolled users. The enrollment module is responsible for enrolling individuals into the biometric system database. In order to facilitate matching, the input digital representation is processed by a feature extractor to generate a compact but expressive representation, called a template. Depending on the application, the template may be stored in the database of the biometric system or be recorded on a *smart card* issued to the individual. Usually, multiple templates of an

individual are stored to account for variations observed in the biometric trait and the templates in the database may be updated over time.

I.6 Measuring the performance of a Biometric System:

There are several parameters that can be used to evaluate performance and to compare different biometric systems. The main important performance parameters are:

a) Failure-to-enroll rate (FTE):

Proportion of the user population for whom the biometric system fails to capture or extract usable information from the biometric sample.

b) Failure-to-acquire rate (FTA):

Proportion of verification or identification attempts for which a biometric system is unable to capture a sample or locate an image or signal of sufficient quality.

c) False-match-rate (FMR):

The rate for incorrect positive matches by the matching algorithm for single template comparison attempts.

d) False-non-match rate (FNMR):

The rate for incorrect negative matches by the matching algorithm for single template comparison attempts.

e) False rejection rate (FRR):

Proportion of authentic users that are incorrectly denied. If a verification transaction consists of a single attempt, the false reject rate would be given by [4]:

$$FRR(\tau) = FTA + FNMR(\tau) * (1 - FTA)$$

f) False acceptation rate (FAR):

Proportion of impostors that are accepted by the biometric system. If a verification transaction consists of a single attempt, the false accept rate would be given by [4]:

$$FAR\ (\tau) = FMR\ (\tau) * (1 - FTA)$$

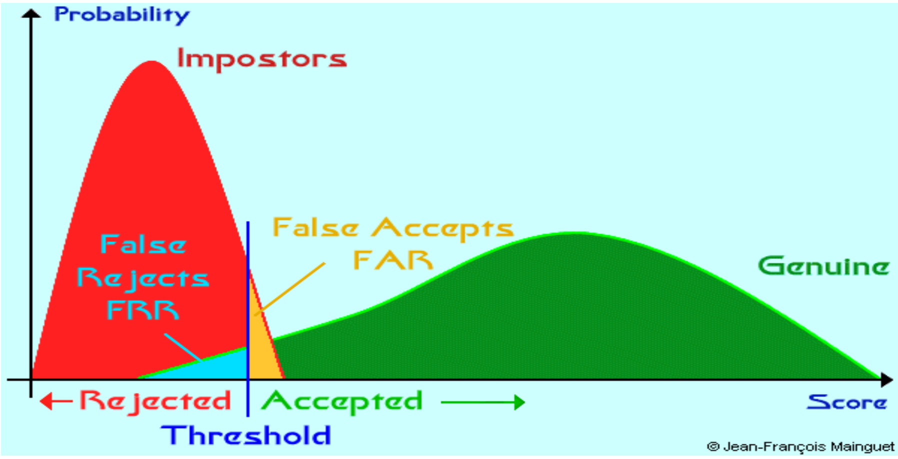


Figure I-13 FAR and FRR diagram.

g) Receiver operating characteristic curve (ROC):

Plot of the rate of FMR as well as FAR (*i.e.*, accepted impostor attempts) on the x-axis against the corresponding rate of FNMR as well as FRR (*i.e.*, rejected genuine attempts) on the y-axis plotted parametrically as a function of the decision threshold.

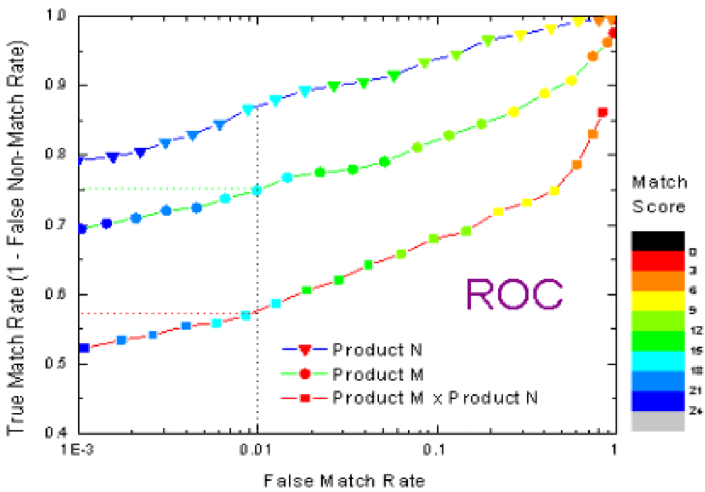


Figure I-14 Example ROC curves.

h) Equal Error Rate (EER):

This error rate corresponds to the point at which the FAR and FRR cross (compromise between FAR and FRR). It is widely used to evaluate and to compare biometric authentication systems. More the EER is near to 0%, the better is the performance of the target system.

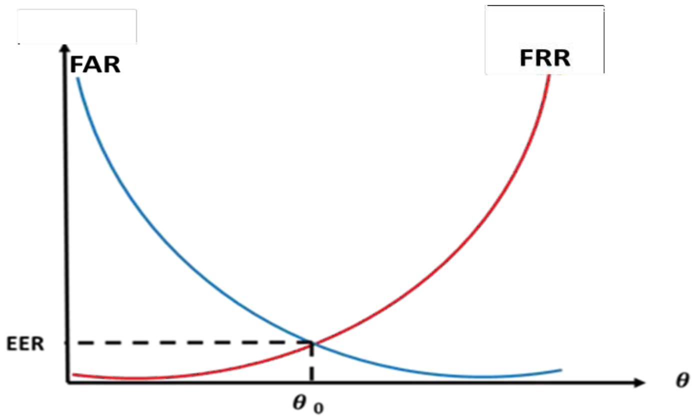


Figure I-15 Equal Error Rate (EER).

I.7 Multimodal Biometric System:

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 System:

Biometric systems that operate using any single biometric characteristic have the following limitations [5]:

1. **Noise in sensed data:** The sensed data might be noisy or distorted. A fingerprint with a scar or a voice altered by cold are examples of noisy data. Noisy data could also be the result of defective or improperly maintained sensors (e.g., accumulation of dirt on a fingerprint sensor) or unfavorable ambient conditions (e.g., poor illumination of a

user's face in a face recognition system). Noisy biometric data may be incorrectly matched with templates in the database resulting in a user being incorrectly rejected.

2. **Intra-class variations:** The biometric data acquired from an individual during authentication may be very different from the data that was used to generate the template during enrollment, thereby affecting the matching process. This variation is typically caused by a user who is incorrectly interacting with the sensor or when sensor characteristics are modified (e.g., by changing sensors—the sensor interoperability problem) during the verification phase.
3. **Distinctiveness:** While a biometric trait is expected to vary significantly across individuals, there may be large inter-class similarities in the feature sets used to represent these traits. This limitation restricts the discriminability provided by the biometric trait. Golfarelli et al. have shown that the information content (number of distinguishable patterns) in two of the most commonly used representations of hand geometry and face are only of the order of and, respectively. Thus, every biometric trait has some theoretical upper bound in terms of its discrimination capability.
4. **Non-universality:** While every user is expected to possess the biometric trait being acquired, in reality it is possible. Effect of noisy images on a biometric system. (a) Fingerprint obtained from a user during enrollment. (b) Fingerprint obtained from the same user during verification after three months. The development of scars or cuts can result in erroneous fingerprint matching results. For a subset of the users to not possess a particular biometric. A fingerprint biometric system, for example, may be unable to extract features from the fingerprints of certain individuals, due to the poor quality of the ridges. Thus, there is a failure to enroll (FTE) rate associated with using a single biometric trait.
5. **Spoof attacks:** An impostor may attempt to spoof the biometric trait of a legitimate enrolled user in order to circumvent the system. This type of attack is especially relevant when behavioral traits such as signature and voice are used. However, physical traits are also susceptible to spoof attacks. For example, it has been demonstrated that it is possible (although difficult and cumbersome and requires the help of a legitimate user) to construct artificial fingers/fingerprints in a reasonable amount of time to circumvent a fingerprint verification system.

I.7.2 Multimodal Biometric System:

As the preceding discussions make clear, using a single biometric modality may not always provide the performance18 needed from a given system. One approach to improving performance (error rates but not speed) is the use of multibiometrics, which has several meanings[6]:

• **Multi-sensors:** Here, a single modality is used, but multiple sensors are used to capture the data. For example, a facial recognition system might employ multiple cameras to capture different angles on a face.

• **Multi-algorithms:** The same capture data are processed using different algorithms. For example, a single fingerprint can be processed using minutiae and texture. This approach saves on sensor and associated hardware costs, but adds computational complexity.

• **Multi-instances:** Multiple instances of the same modality are used. For example, multiple fingerprints may be matched instead of just one, as may the irises of both eyes. Depending on how the capture was done, such systems may or may not require additional hardware and sensor devices.

• **Multi-samples:** Multiple samples of the same trait are acquired. For example, multiple angles of a face or multiple images of different portions of the same fingerprint are captured.

• **Multimodal:** Data from different modalities are combined, such as face and fingerprint, or iris and voice. Such systems require both hardware (sensors) and software (algorithms) to capture and process each modality being used.

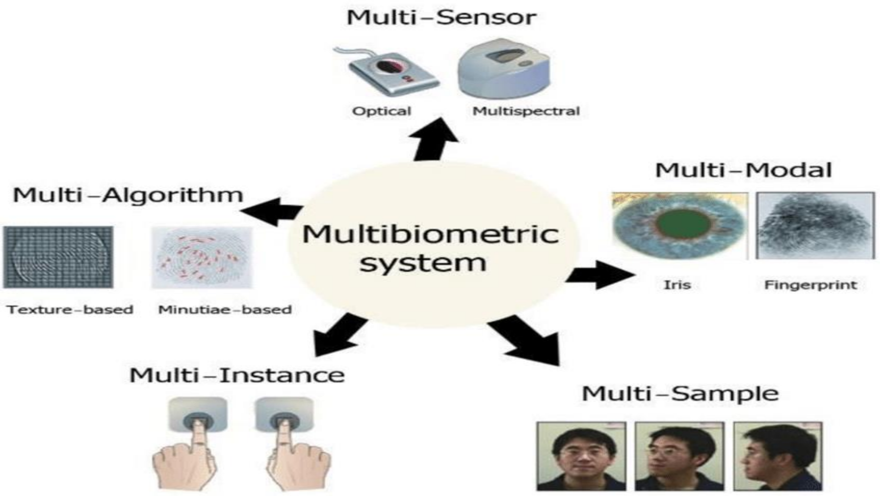


Figure I-16 The different types of multi-biometric system.

I.7.3 Fusion in Multi Modal Biometric Systems:

Multimodal biometric systems integrate information presented by multiple biometric indicators. The information can be consolidated at various levels. These are as follows.

a) Fusion at the feature extraction level:

The biometric parameters of each different feature are joined to produce a new set of features as shown in figure (I-17):

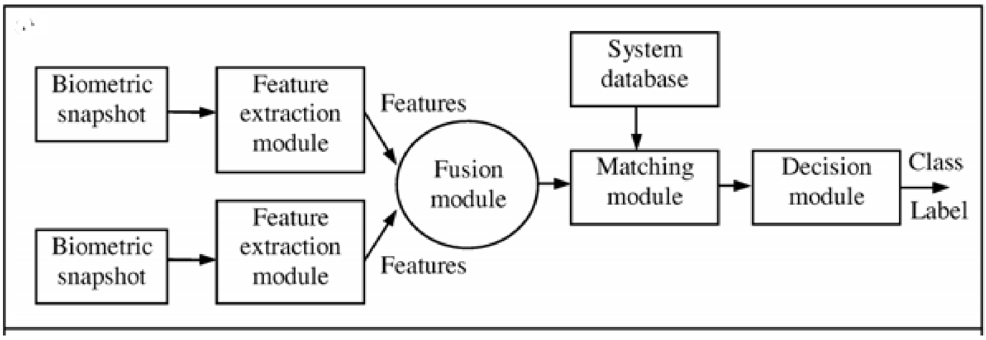


Figure I-17 Feature level Fusion.

b) Fusion at the matching score (confidence or rank) level:

The matching scores are acquired from the biometric parameters of each different feature and are fused by different techniques. See figure (I-18).

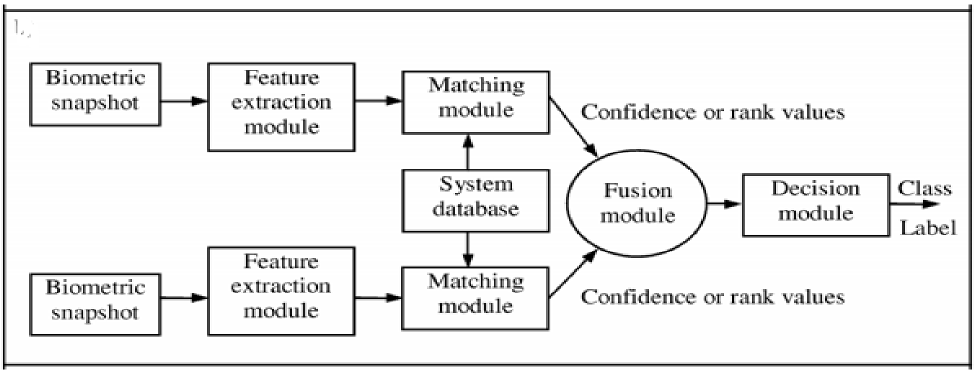


Figure I-18 Matching Score level Fusion.

c) Fusion at the decision (abstract label) level:

The resulting features from multiple biometric data are fused individually to classify either accept or reject. As shown in figure (I-19).

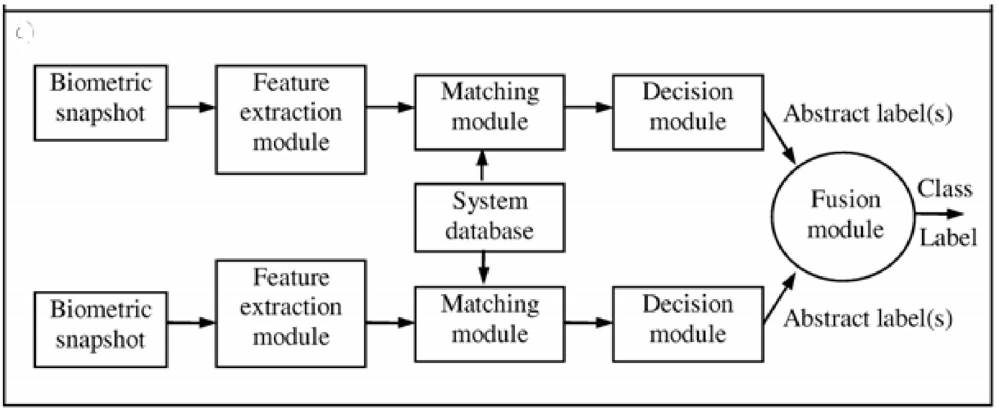


Figure I-19 decision level Fusion.

I.8 Biometric application:

This is some of the biometric application in our life [7]:

I.8.1 Airport security:

Iris recognition has been used in a number of large airports for several years. You must sign up to a scheme and your eyes and iris are scanned. Your details are then stored on an international database and instead of waiting in long passport queues, passengers simply walk into a booth and look into a camera. The software then scans the iris and matches the details with the information stored on the database.

I.8.2 Building Access:

Fingerprint access for buildings is not new. Many high security facilities have used biometric technology for years when it comes to ensuring only authorised personal gain access to the most well protected establishments.

I.8.3 Cars:

It is estimated that over 2 million cars in the UK use biometric technology in one form or another. This can be anything from voice recognition when using Bluetooth or entertainment systems to unlocking the vehicle itself.

I.8.4 Blood Banks:

When it comes to giving blood; identity is pretty important. In the past donors were issued with blue cards containing all the information required. More and more these days that crucial data is being stored digitally – with donors using fingerprint or iris recognition to access their vital details.

I.9 Conclusion:

Biometric techniques for identification and authentication have a future. However, given the importance of the risks associated with the use of biometric systems, and their possible legal consequences (for authentication purposes, in particular), it is important that the legislation strictly regulates their conditions of use.

One of the major problems in biometric systems is to find a competitive representation of biometric features. The effectiveness of extraction method will have a great impact on biometric system performance.

In the following chapter, we will propose a feature extraction algorithm based on fuzzy logic system.

chapter II :

Feature extraction based on fuzzy modeling

II.1 A Brief History of Fuzzy Logic:

The idea of fuzzy logic was first introduced by Dr. Lotfi Zadeh at the University of California at Berkeley the 1965 and it has been continually expanded by researchers worldwide to the present. However, it was not initially welcomed in the academic community due to some of its underlying mathematics not yet being explored, thus associated applications developed slowly. One of the most famous objectors to fuzzy logic was Professor William Kahan, a colleague of Dr. Zadeh at UC Berkeley [8].

Fuzzy logic systems, as presented in their mathematical framework, have the ability to reproduce some system behavior as dynamical response, nonlinear functions... This important feature is known as 'universal approximation'.

In this chapter and firstly, we will examine the main notions in fuzzy logic systems. In second, we will formulate the problem of feature extraction as finding an appropriate fuzzy system thought minimization problem of error function. Enhanced gradient method will be proposed to find optimal solution.

II.2 Introduction to Fuzzy Logic:

In traditional, classical logic, conclusions are always either true or false. However, in our world there are many propositions with variable answers, such as one might find when asking a group of people to share their feelings about the dishes in a restaurant. In this example, ‘true’ means people are completely satisfied with this meal and extremely happy with this restaurant’s services. Meanwhile, ‘false’ represents some people have a horrible feeling about the meal and being totally disappointed with the services. Fuzzy logic provides the degrees of truth and probabilities range between 0 and 1. In such instances, the feedback scores should be variable from 0 to 1, which means that the diner’s opinion on the meal and restaurant services would be between total disappointment and complete satisfaction. Fuzzy logic has been applied to many fields, including control theory, decision making, and AI [8].

II.3 Fuzzy logic system:

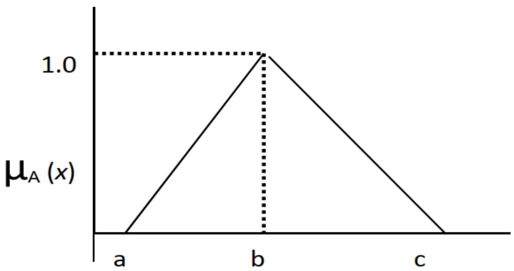
Fuzzy logic is an extension of classical binary logic, with the purpose of providing a framework for approximate reasoning. In practical terms, fuzzy logic is based on the theory of fuzzy sets, which extend the value of true and false from the classical logic to an arbitrary degree of truth, with specific values between 0 and 1. The basic concept of fuzzy logic theory applied the set theory with the main purpose of demonstrating the implementation of mathematical functions in hardware circuits [9]. Fuzzy logic was implemented with maximum and minimum operations in hardware using diodes and resistor circuits to form a “logical block”, in a process dubbed “analogue logic”.

II.3.1 Membership functions:

Membership function are the representation of values in fuzzy domain ,Many types of membership functions (μ) can be used. There are generally several types of membership functions, which are used for the fuzzification process: Trapezoidal and triangular membership functions as shown, respectively in figures (II-1,2).Also, the Gaussian membership function Figure(II-3), a singleton membership function (II-4). A fuzzy singleton includes only one element. Once the element x is defined, the corresponding fuzzy set is accordingly defined [10]. The trapezoidal and Gaussian are the most commonly used functions.

a) Triangular Membership function:

Let a, b and c represent the x coordinates of the three vertices of μA (x) in a fuzzy set A (a: lower boundary and c: upper boundary where membership degree is zero, b: the center where membership degree is 1).



$$\mu_A(x) = \begin{cases} 0 & if\ x \le a \\ \dfrac{x-a}{b-a} & if\ a \le x \le b \\ \dfrac{c-x}{c-b} & if\ b \le x \le c \\ 0 & if\ x \ge c \end{cases}$$

Figure II-1 Triangular Membership function.

b) Trapezoidal membership function:

Let a, b, c and d represents the x coordinates of the membership function. then

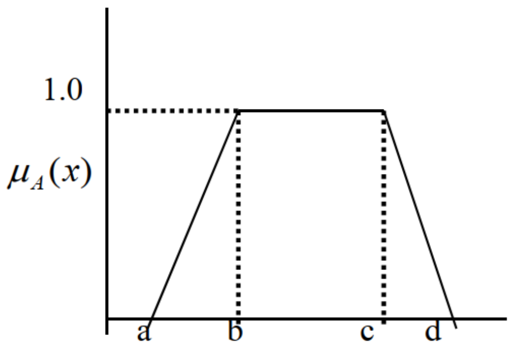
Trapezoid(x; a, b, c, d) = 0 if x ≤ a;

= (x-a)/ (b-a) if a ≤ x ≤b

= 1 if b ≤ x ≤c;

= (d-x)/ (d-c) 0 if c ≤ x ≤ d;

= 0, if d ≤ x



$$\mu_{\text{trapezoid}} = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right)$$

Figure II-2 Trapezoidal membership function.

c) Gaussian membership function: It is defined by two parameters {σ, m}:

$$\mu(x) = \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right)$$

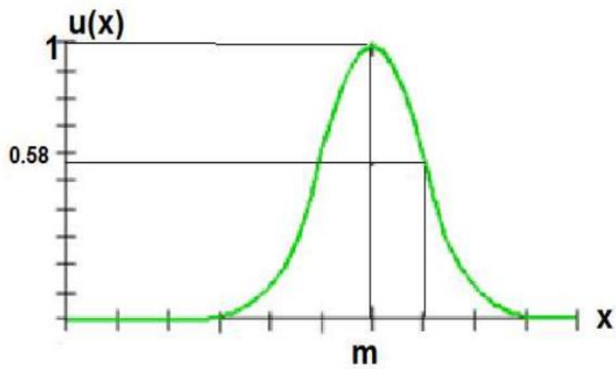


Figure II-3 Gaussian membership function.

d) 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-4).

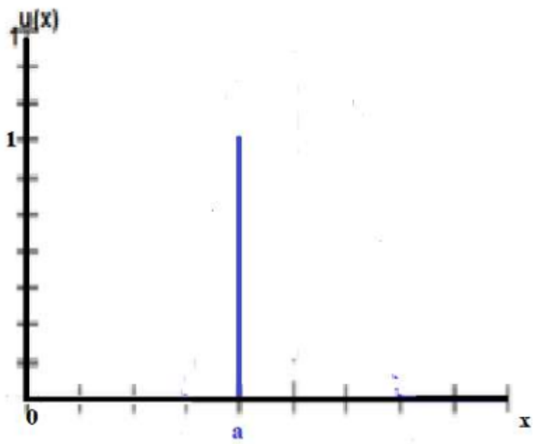


Figure II-4 Singleton function.

II.3.2 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 :$\mu A\cap B\ x = \mu\ A$ AND $B = min\ \mu A\ x\ , \mu B(x)$

b) Union: $\mu A\cup B\ x = \mu\ A$ OR $B = max\ \ , \mu B(x)$

c) Complement: $\mu A\ x = \mu$ 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. Because the standard binary logic is a special case of fuzzy logic where the membership values are always 1 (completely true) or 0 (completely false), fuzzy logic must hold the consistent logical operations as the standard logical operations. The most foundational logical operations are AND, OR and NOT. Unlike standard logical operation, the operands A and B are membership values within the interval [0, 1]. In fuzzy logical operations, logical AND is expressed by function min, so the statement A AND B is equal to min (A,B). Logical OR is defined by function max, thus A OR B becomes equivalent to max (A, B). And logical NOT makes operation NOT A become the operation 1 – A

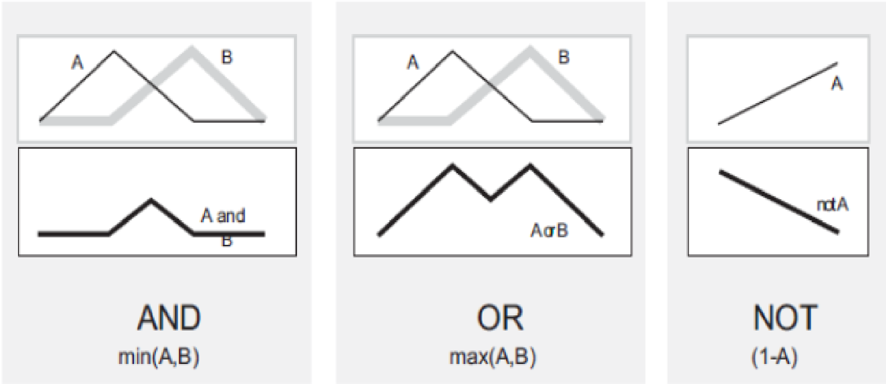


Figure II-5 Fuzzy logical operations.

II.3.3 If-Then Rules:

In fuzzy inference process, parallel If-Then rules form the deducing mechanism, which indicates how to project input variables onto output space. A single fuzzy If-Then rule follows the form:

If **x** is **A**, Then **y** is **B**

The first If-part is called the antecedent, where **x** is input variable. The rest Then-part is called the consequent, and **y** is output variable. The reason why If-Then conditional statements are universally applicable is because both **A** and **B** are linguistic values, or adjectives in most cases, and this form of conditional statement works the concordant way with human judgment.

II.3.4 Fuzzy system modules:

A FLS consists of four main parts: fuzzifier, rules, inference engine, and defuzzifier. These components and the general architecture of a FLS is shown in Figure (II.6).

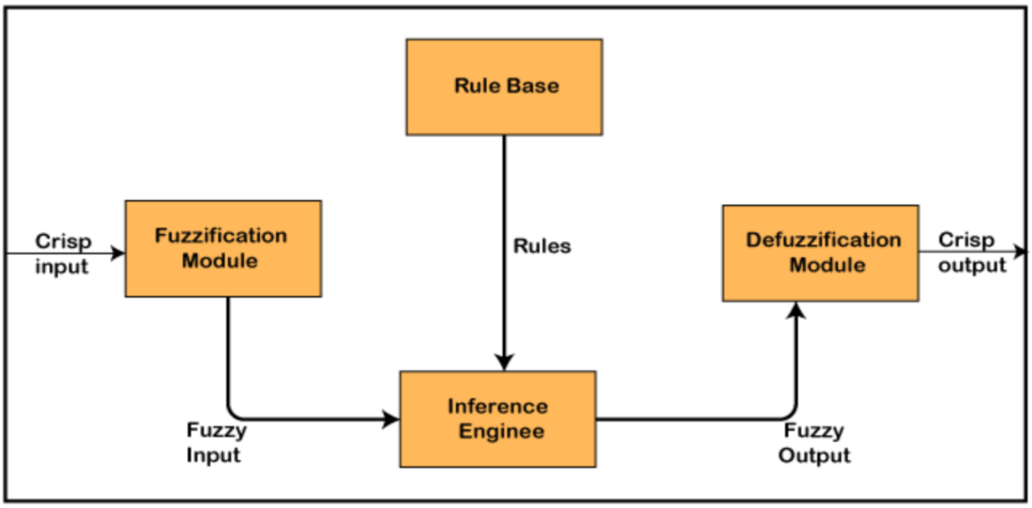


Figure II-6 Structure of fuzzy logic system

a) Fuzzification Module:

Fuzzyfication is a process that converts crisp values into linguistic terms (linguistic variables), which are later quantified by fuzzy membership function using fuzzy sets. Linguistic variables are the input or output variables of the system whose values are words or sentences from a natural language, instead of numerical values. Each fuzzy set expresses particular linguistic term. Fuzzyfication is the process of changing a real scalar value into a fuzzy value; this translates accurate crisp input values into linguistic variables.

b) Defuzzification Module:

The Defuzzification Module receives the processed information from the Inference Engine. This information contains the conclusion, but still, it is not in the form in which it was received, i.e. user-understandable form. So, the defuzzification module again converts this information into a form which is well accepted by the user.

c) Inference Engine:

The Inference engine is the main component of the Fuzzy Logic System. If compared with the computer parts, our inference engine is the same as the processor of the computer. All the processing of the information takes place inside it. The task of the inference engine is to draw a valid result by analyzing and concluding all the information that it gets from the fuzzification module. This is again done by referring to the rules and prior information present in the Knowledge Base. The final conclusions made are then sent for further modification to the defuzzification module.

d) Rule Base:

Rule Base is a component used for storing the set of rules and the If-Then conditions given by the experts are used for controlling the decision-making systems. There are so many updates that come in the Fuzzy theory recently, which offers effective methods for designing and tuning of fuzzy controllers. These updates or developments decreases the number of fuzzy set of rules.

II.3.5 Type of Fuzzy Inference System:

Fuzzy inference is the process of mapping the given input variables to an output space via fuzzy logic based deducing mechanism which is comprised by If-Then rules, membership functions and fuzzy logical operations. Because the form of If-Then rule fits in human reasoning, and fuzzy logic approximates to people's linguistic habits, this inference process projecting crisp quantities onto human language and promptly yielding a precise value as result is widely adopted Generally, three types of fuzzy inference methods are proposed in literature: Mamdani fuzzy inference, Sugeno fuzzy inference, and Tsukamoto fuzzy inference [11]. All of these three methods can be divided into two processes.

a) Mamdani-Type Fuzzy Inference Process:

Mamdani fuzzy inference was first introduced as a method to create a control system by synthesizing a set of linguistic control rules obtained from experienced human operators. In a Mamdani system, the output of each rule is a fuzzy set.

Mamdani-type fuzzy inference process consists of five steps:

Step 1: Fuzzify input variables

Step 2: Apply fuzzy operator

Step 3: Apply implication method

Step 4: Apply aggregation method

Step 5: Defuzzification

b) Sugeno Fuzzy Inference Systems (TS):

Sugeno fuzzy inference also referred to as Takagi-Sugeno-Kang fuzzy inference, uses *singleton* output membership functions that are either constant or a linear function of the input values. The defuzzification process for a Sugeno system is more computationally efficient compared to that of a Mamdani system, since it uses a weighted average or weighted sum of a few data points rather than compute a centroid of a two-dimensional area.

The first two parts of the fuzzy inference process, fuzzifying the inputs and applying the fuzzy operator, are exactly the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant. A typical rule in a Sugeno fuzzy model has the form: **If Input 1 =** ***x*** **and Input 2 =** ***y*** **,then Output is** ***z=ax+by+c***

For a zero-order Sugeno model, the output level z is a constant (a=b =0). The output level zi of each rule is weighted by the firing strength w of the rule. For example, for an AND rule with Input 1 = x and Input 2 = y, the firing strength is:

$$w_i = \text{AndMethod}\,(F1(x), F2(y))$$

where F1,2(.) are the membership functions for Inputs 1 and 2. The final output of the system is the weighted average of all rule outputs, computed as:

$$\text{Final Output} = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i}$$

Where **N** is the number of rules

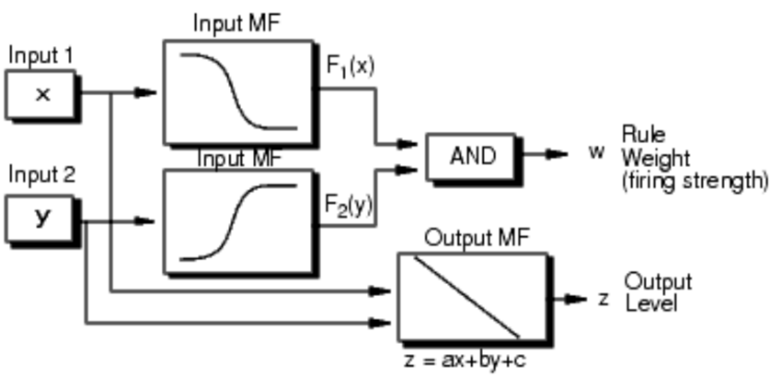


Figure II-7 Sugeno Fuzzy Inference Systems.

II.3.6 Advantages of the Sugeno Method:

• It is computationally efficient.
• It works well with linear techniques (e.g., PID control).
• It works well with optimization and adaptive techniques.
• It has guaranteed continuity of the output surface.
• It is well suited to mathematical analysis.

II.4 Universal approximation:

In the literature, we find an important property that makes fuzzy systems useful in modeling and identification problems. In several research works [12], 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 $\boldsymbol{I^*(x)}$ with the input vector $\boldsymbol{x \in R^n}$ can be approximated by a fuzzy model $\boldsymbol{\hat{I}(x)}$ such that the error $\boldsymbol{\delta\ (x)} = \left|\boldsymbol{I}^*(\mathbf{x}) - \hat{\mathrm{I}}(\mathbf{x})\right|$ 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.5 Image modeling by TS-FIS (Takagi-Sugeno):

The image known as a physical likeness or representation of a person, animal, or thing, photographed, painted, sculptured, or otherwise made visible. A digital image is an image composed of picture elements, also known as pixels, each with finite, discrete quantities of numeric representation for its intensity or gray level that is an output from its two-dimensional functions fed as input by its spatial coordinates denoted with x, y on the x-axis and y-axis, respectively .

Grayscale image is one of the images type's, each pixel is assigned a grayscale level that presents luminance of the pixel, when grayscale images are represented by matrices each element of the matrix determines the intensity of the corresponding pixel. For convenience, most of the current digital files use integer numbers between 0 (to indicate black, the color of minimal intensity) and 255 (to indicate white, maximum intensity).

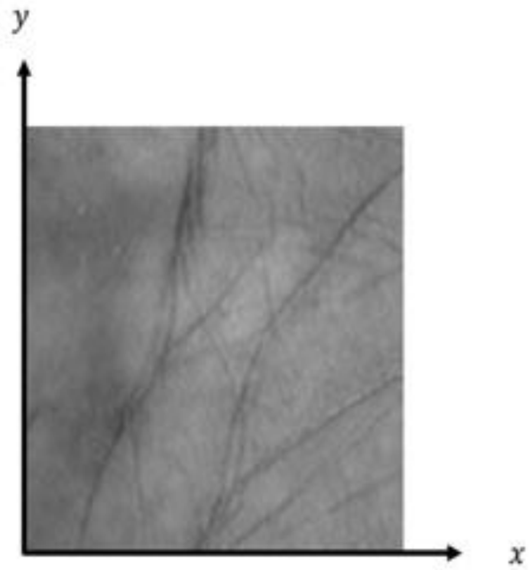


Figure II-8 Figure grayscale image .

It is clear that pixel gray level change versus its position, so we propose to define the image, associated function I*(x, y). From previous discussion, it is possible to approximate such function by FIS (Takagi-Sugeno) model to reproduce the gray level with sufficient accuracy and we can write [13]:

$$\mathbf{I^*(x, y) = \xi^{\mathit{T}}(x, y).\boldsymbol{\theta}} \qquad \textbf{(II-1)}$$

The remainder problem will be the identification of the parameter vector that produces acceptable errors. We propose that parameter vector will constitute the feature vector of the modality.

II.6 Quadratic problem formulation:

We consider a function associated with a biometric image given by $(\boldsymbol{x}, \boldsymbol{y})$ and a fuzzy approximation model $\mathbf{I^*(x, y) = \xi^{\mathit{T}}(x, y).\boldsymbol{\theta}}$. We propose the determination of the vector $\boldsymbol{\theta}$ through the minimization of the following criterion:

$$(\boldsymbol{\theta})=\boldsymbol{\Sigma_i\Sigma_j}\left|\mathbf{I}(\mathbf{x}_i,\mathbf{y}_j)-\boldsymbol{\xi}^{\boldsymbol{T}}(\mathbf{x}_i,\mathbf{y}_j).\boldsymbol{\theta}\right|^2 \qquad \textbf{(II-2)}$$

Where $(\boldsymbol{xi}, \boldsymbol{yj})$ is gray level of image pixel with coordinates $(\boldsymbol{x}, \boldsymbol{y})$. Our objective is to find an optimal vector $\boldsymbol{\theta}$ such that**:**

$$\widehat{\boldsymbol{\theta}} = \boldsymbol{argmin_\theta}(\mathbf{J}(\boldsymbol{\theta})) = \boldsymbol{argmin_\theta}\left(\boldsymbol{\Sigma_I\Sigma_J}\left|\mathbf{I}(\mathbf{x}_i,\mathbf{y}_j)-\boldsymbol{\xi}^{\boldsymbol{T}}(\mathbf{x}_i,\mathbf{y}_j).\boldsymbol{\theta}\right|^2\right) \qquad \textbf{(II-3)}$$

After development, we find the cost function expression in a matrix quadratic form:

$$(\theta) = \Sigma_i \Sigma_j \left(I^2(xi, yj) - 2.I\,(xi, yj)\ \xi^T(xi, yj).\theta + \theta^T \xi\,(xi, yj).\ \xi^T(xi, yj).\theta \right)$$

In matrix form:

$$(\theta) = \frac{1}{2}\theta^T A\,\theta + B^T\theta + c \qquad \text{(II-4)}$$

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

$$A = 2\Sigma_i \Sigma_j \xi(xi, yj)\xi^T(xi, yj)$$

$$B = -\Sigma_i \Sigma_j 2.I(xi, yj)\xi^T(xi, yj)$$

$$C = \Sigma_i \Sigma_j I^2(xi, yj)$$

It is clear that the criterion is now reformulated as a quadratic function, in this compact quadratic form, the unknown parameter vector appears separated from the know functions. Therefore, now we can use one of several methods to resolve quadratic problems, we known as optimization methods. In this chapter, we will apply gradient method.

II.7 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. Conjugate gradient methods represent an important class of unconstrained optimization algorithms with strong local and global convergence properties and modest memory requirement [14].

The ideal method for solving large-scale systems is the conjugate gradient (CG) method, which forms an important class of algorithms used in solving large-scale unconstrained optimization problems. The method is popular with mathematicians and engineers engaged in large-scale problems because of it low memory requirement and strong global convergence properties [15]. In the recent literature, we find a modified gradient method proposed by DAi-Yuan in his research paper [16]. Therefore, we propose to adequate this algorithm to our problem.

II.7.1 The Dai–Yuan conjugate gradient algorithm:

For solving the unconstrained optimization problem

$$\min\{J(x): x \in R^n\} \quad \text{(II-5)}$$

Where $f : R^n \to R$ is continuously differentiable and bounded below we consider a nonlinear conjugate gradient algorithm:

$$\theta_{k+1} = \theta_k + \alpha_k d_k, \quad \text{(II-6)}$$

Where the step size $\alpha_k$is positive and the directions d_k are computed by the rule:

$$d_{k+1} = -Nu_{k+1} g_{k+1} + \beta_k^N s_k \qquad d_0 = -g_k \quad \text{(II-7)}$$

Where

$$\beta_k^N = \frac{\|g_{k+1}\|^2}{(y_k^T s_k)} - \frac{\|g_{k+1}\|^2 (s_k^T g_{k+1})}{(y_k^T s_k)^2} \quad \text{(II-8)}$$

and Nu_{k+1} is a parameter to be determined which follows. Here $y_k = g_{k+1} - g_k$ and $S_k = \theta_{k+1} - \theta_k$.

The line search in the conjugate gradient algorithms for α_k computation is often based on the standard Wolfe conditions [17]:

$$J(x_k + \alpha_k d_k) - J(x_k) \le \rho \alpha_k g_k^T d_k,$$

$$g_{k+1}^T d_k \ \ge \ \sigma g_k^T d_k, \quad \text{(II-9)}$$

Where d_k is a descent direction and $0 < \rho \le \sigma < 1$.

We were led to this computational scheme by modifying the Dai and Yuan algorithm, β_k^N ***is** a proper modification of the* β_k^{DY}:

$$\beta_k^{DY} = \frac{g_{k+1}^T g_{k+1}}{y_k^T S_k},$$

To determine the parameter Nu_{k+1} we suggest the following procedure: When the initial point $\boldsymbol{\theta_0}$ is near the solution of (**II-5**)and the Hessian of function J is a nonsingular matrix we know that the Newton direction is the best line search direction. Therefore, to get a good algorithm for solving **(II-6)** this is a very good motivation to choose the parameter nu_k in such a way that for every k ≥ 1 the direction d_{k+1} given by **(II-7)**is the Newton direction. Therefore, from the equation:

$$-\nabla^2 \mathbf{J}\ (\theta\ \mathbf{k+1})^{-1}\mathbf{gk+1}\ = \boldsymbol{Nu_{k+1} g_{k+1}} + \boldsymbol{\beta_k^N s_k},$$

after some algebra we get[18] :

$$\boldsymbol{Nu_{k+1}} = \frac{\|\boldsymbol{g_{k+1}}\|^2}{\|\boldsymbol{g_{k+1}}\|^2 - \boldsymbol{g_k^T g_{k+1}}}\left[\mathbf{1} - \frac{(\boldsymbol{s_k^T g_{k+1}})}{\boldsymbol{y_k^T S_k}}\right]$$

In [4] Dai and Yuan proved the global convergence of a conjugate gradient algorithm for which $\beta_k = \beta_k^{DY} t_k$, $t_k \in [-c, 1]$with $c= (1 - \sigma) / (1+\sigma)$.

Observe that

$$\boldsymbol{\beta_k^N} = \frac{\|\boldsymbol{g_{k+1}}\|^2}{\boldsymbol{y_k^T s_k}}\left[\mathbf{1} - \frac{(\boldsymbol{s_k^T g_{k+1}})}{\boldsymbol{y_k^T s_k}}\right] = \boldsymbol{\beta_k^{DY} r_k}, \quad \text{where } \boldsymbol{r_k} = \mathbf{1} - \frac{\boldsymbol{s_k^T g_{k+1}}}{\boldsymbol{y_k^T s_k}}.$$

And we proved that **:** $\boldsymbol{s_k^T g_{k+1}} \geq \frac{-\boldsymbol{\sigma}}{\mathbf{1}-\boldsymbol{\sigma}} \boldsymbol{y_k^T S_k}$.

Finally:

$$\boldsymbol{\beta_k^N} \leq \boldsymbol{\beta_k^{DY}} \frac{-\boldsymbol{\sigma}}{\mathbf{1}-\boldsymbol{\sigma}}.$$

II.7.2 Dai-Yuan conjugate Gradient method Organigram:

From the above mathematical analysis, the studied minimization method can be achieved following the algorithm given by:

Step0: (initialization)

Let $\boldsymbol{\theta_0}$ be the starting point, pose $d_0 = -g_0$

Pose k=0 and go to step 1.

Step1:

$g_k = \nabla J(\boldsymbol{Nu}_k),$

If $g_k = 0$: STOP ($\boldsymbol{\theta}^* = \boldsymbol{\theta}_k$). "Stop test"

If not go to step 2

Step2:

Define $\boldsymbol{\theta}_{k+1} = \boldsymbol{\theta}_k + \alpha_k d_k$

$$\beta_k^{DY} = \frac{g_{k+1}^T g_{k+1}}{y_k^T s_k}$$

$$Nu_{k+1} = \frac{\|g_{k+1}\|^2}{\|g_{k+1}\|^2 - g_k^T g_{k+1}}\left[1 - \frac{(s_k^T g_{k+1})}{y_k^T s_k}\right]$$

$$d_{k+1} = -Nu_{k+1} g_{k+1} + \beta_{k+1}^{DY} d_k$$

Define k= k+1 and go to step 1.

The previous algorithm can be illustrated by the organigram of the figure(0-1) :

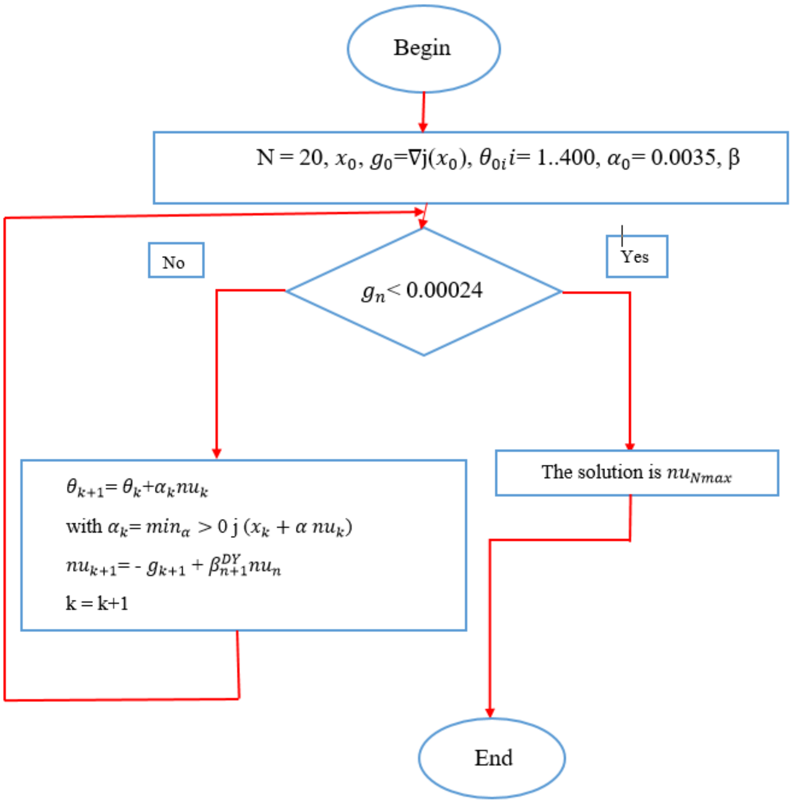


Figure II-9 Organigram of Modified Gradient method.

II.8 Discussion:

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_0). 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, which appear affine in unknown parameters vector.

II.9 Conclusion:

In this chapter, we have presented the main tools necessary for image modeling by a TS-type fuzzy system. The particular writing of the output of a fuzzy model of TS, allowed us to formulate a quadratic criterion to minimize. The conjugate gradient algorithm, as presented, offers a recursive procedure to determine the vector of unknown parameters of the fuzzy model. In the next chapter, we will apply this algorithm in the context of a biometric system.

chapter III :

Experimental results and discussion

III.1 Introduction:

This chapter represents experimental results of a palm biometric identification system. We will use the Dai-Yuan conjugate decent algorithm to find an appropriate feature vector as developed in the previous chapter with a PolyU multispectral palmprint database that will be used in the evaluation of proposed biometric system [19].

III.2 Palmprint Recognition

The palmprint is the inside part of the hand from the wrist to the roots of the fingers, with his large surface and the abundance of the biometric traits, it is expected that the palm prints are very robust to noise and unique to each individual. The palm surface consists of many unique features such as principal lines, ridges, wrinkles as shown in figure **(III-1)**.

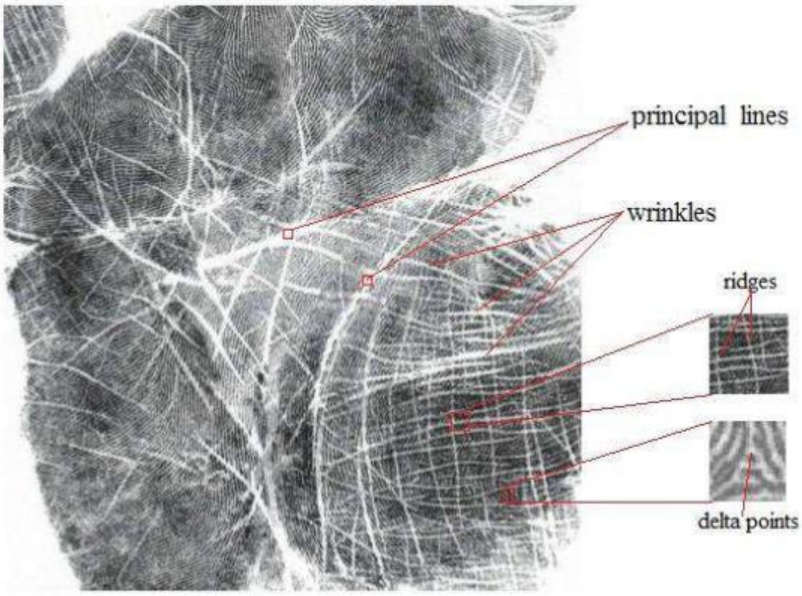


Figure III-1: The three principal lines on a typical palm

III.3 Proposed biometric system

We propose a multimodal biometric system (Multi-samples) based on modality of palmprint and with fusion at score level (see Figure **(III-2)**). The system consists of four modules: biometric capture (palmprint image), feature extraction module comparison module and decision module [20].

In the biometric capture, 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 Comparison 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.

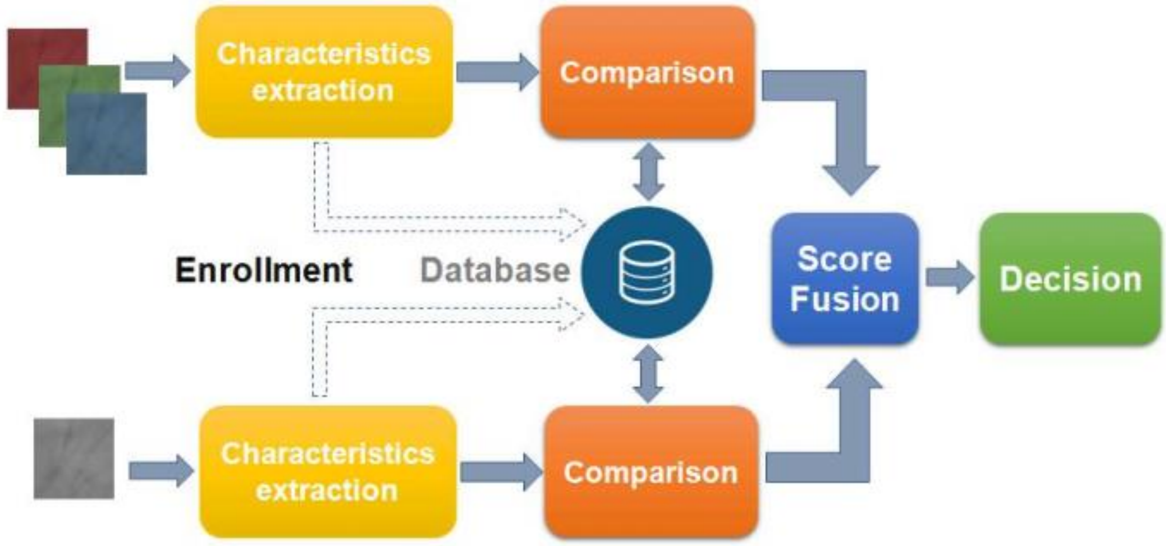


Figure III-2: Multimodal system (with fusion at score level).

III.4 Palmprint image acquisition device

To achieve effective palmprint identification in real time, it is required to have a particular device that must be faster in the acquisition of palm prints. An example of such a device is shown in figure **(III-3).**

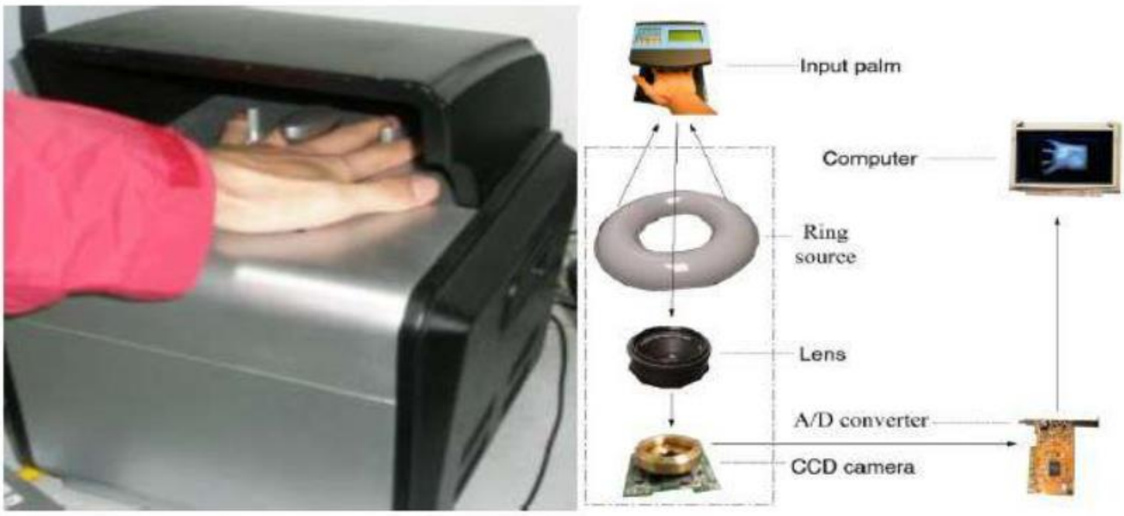


Figure III-3 the structure of the palmprint image acquisition device.

III.4.1 Features Extraction

The feature extraction step allows constructing vectors containing the discriminant characteristics of an image of a biometric modality (palmprint) obtained with a biometric sensor and recorded in a database as mathematical values.

In the previous chapter, we have shown that the fuzzy system is a universal approximator, based on this advantage we will use the Newton Raphson algorithm to find fuzzy model corresponding to the considered image. A vector of these parameters will be considered as biometric feature vector.

III.4.2 Palmprint images database

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.

The database has 6000 images obtained from 500 persons. The images were taken in two different sessions separated by a time interval of about two months. During each period, each individual had to take at least 6 pictures of his palmprint. Then in the second period, the light source and the (CCD) camera lens are adjusted so that the images of the first and second session gave the impression of having been taken by different light condition to test the robustness of the biometric system. However, the extracted ROI sub-image size is equal to 128 x 128 with a resolution of 75 dpi. Finally, we note that the acquisition system collect 4 images from a single hand (Red, Green, Blue and NIR) [21].

To develop a palmprint recognition application, it is necessary to have two databases: the first base to perform the learning and the second to test the techniques and determine their performance, but there is no rule for determine this dividing quantitatively. In this case, we will rely on a method based on the available data and the time needed to complete the learning process.

a) Learning images: at this step the first one, are processed.

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

III.5 Results and Discussion:

III.5.1 Development Environment:

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

a) Hardware environments:

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

- ❖ Laptop : ASUS-PC

- Memory (RAM): 8.00 Go.
- Processor: Intel (R) Core (TM) i5-8250U CPU @ 1.80 GHz.
- System Type: 64-bit Operating System.

b) Software environments:

For the development of this application, we used the following software tools: Matlab 9.4.0 (R2018a).

III.5.2 Working Protocol

III.5.2.1 Parameters Adaptation

The objective of parameters adaptation is to estimate these parameters, which assure finding a desirable performance. From this objective, we organize our experience into three principal steps.

In our experimental study, variables of the proposed system have to be initialized and the parameters of the adopted optimization algorithm of Dai-Yuan conjugate gradient method have to be set. Therefore, we choose the following values:

Table III-1 parameter values and variable initialization

Parameter values and variable initialization	symbols	values
Stop condition	$\|\|g_n\|\|$	Inferior than 0.00024
Number of membership functions for each variable	N	20
Membership functions type for each variable		triangular
Number of rules		400
Initialization of parameters vector	$\theta_{0i}\ i = 1..400$	90
Initial value	α_0	0.0035

In step 1, we have fixed the fuzzy membership functions with 20 functions. In the same time, we varied the number of iterations associated to the « conjugate gradient » method between 5 and 20 iterations with a step of 5 to determine the best results for the « NIR » band. We distinguish two functioning modes.

a) In Open Mode: We measured the performance based on two essential parameters, which are **EER** and the threshold $\boldsymbol{\theta_0}$.

b) In closed mode: We measured the performance through (ROR) and (RPR). The table III-2 summarizes the variation of iterations with taking into account the values of **EER**; **ROR** and **RPR**, with max number of iterations Nmax = 10, we obtain the best results (**EER=0.208**) without improvement when this number augmenting.

For the **ROR**, we can say the rate of **98.86%** presents the best result for the **5, 10, 15** and **20** iterations. For the **RPR**, we notice that the value of **69** is the best, and this value suggests that **10** iterations is the best choice. In addition, the time of execution of the latter is relatively small.

Table III-2 : Results of EER, ROR and RPR according to the number of iterations

NIR Band	Open Mode	Closed Mode	
N (number of iteration)	EER	ROR (%)	RPR
5	0.311	97.6	90
10	0.208	98.86	69
15	0.298	98.13	80
20	0.305	98.01	130

For this reason in step 2, we fix the number of iterations in 10 and we begin to vary the number of fuzzy membership functions. In following, the table (III-3) represents the results of (EER, ROR, and RPR) of this variation.

Table III-3 : Influence of membership functions number

NIR Band	Open Mode	Closed Mode	
Nfa (number of membership functions	EER	ROR	RPR
10	0.811	85.29	170
20	0.208	98.86	69
30	0.213	97.4	86

Through reading this table, we notice that the best results obtained match with a membership function number **Nfa = 20**. **EER=0.208, ROR=98.86** and **RPR= 69**.

In next, we will treat the case of unimodal system with its different specters. We will choose **number of iterations equal to 10** and **number of membership functions equal to 20**, also for a multispectral application (across all bands of images).

III.5.2.2 Unimodal Application

As we have seen in the first chapter of this memory, the biometric system can work in two modes: an open mode or a closed mode.

This table shown below represents the values of relative parameters in open mode and closed mode for the variety of images bands (Blue, Red, Green, and NIR)

Table III-4 : Results of EER, ROR and RPR for differnt unimodal bands

Modality	Open Mode		Closed Mode	
	EER (%)	Threshold θ_0	ROR (%)	RPR
BLUE	0.222	0.1834	**99.68**	481
NIR	**0.208**	**0.1719**	98.86	69
RED	1.129	0.1742	96.13	365
GREEN	6.95	0.1625	82.22	490

The reading of this table permits us to conclude on the quality of the results for the different bands like this:

1) The NIR is the best band, because its **EER** is on minimum. However, with acceptable **ROR= 98.86** it takes the second place.
2) The blue band is preferable mainly in closed mode. With a maximum **ROR= 99.68 %,** it performs best in recognition rate. However, in open mode it becomes after NIR band.
3) The RED band despite having the worst **EER** among the four bands, its **ROR=96.13%** is relatively acceptable since it is not far from blue and NIR bands.
4) From all bands, the GREEN one registered the worst results.

- **Graphical Interpretation**

The figure (III-4) shows the characteristic curves (*Receiver Operating Characteristic* (**ROC**)) of the system, in the open mode for the four image bands of the palmprint (Blue, NIR, Red, and Green). This figure represents the distribution of values of **EER**, which are cited in the previous table on each intersection between the first bisector and the **ROC** curves of images band that are mentioned previously.

This figure classifies the previous bands based on the **EER** values; in this case, we notice that the best band is the NIR one because it has the **EER** compared to the other bands, the latter equals to **0.222** achieved by BLUE band.

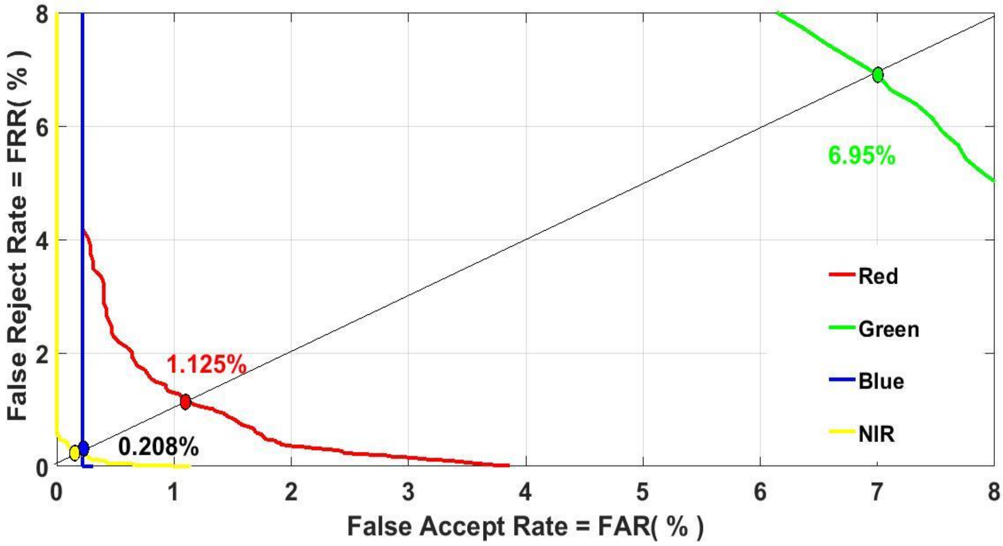


Figure III-4 Unimodal system performance (ROC)

Then, we have tested the performance of an identification system working in a closed mode. The figure (III-5) shows the cumulative curves (Cumulative Match Curve (**CMC**)) of different images bands based system.

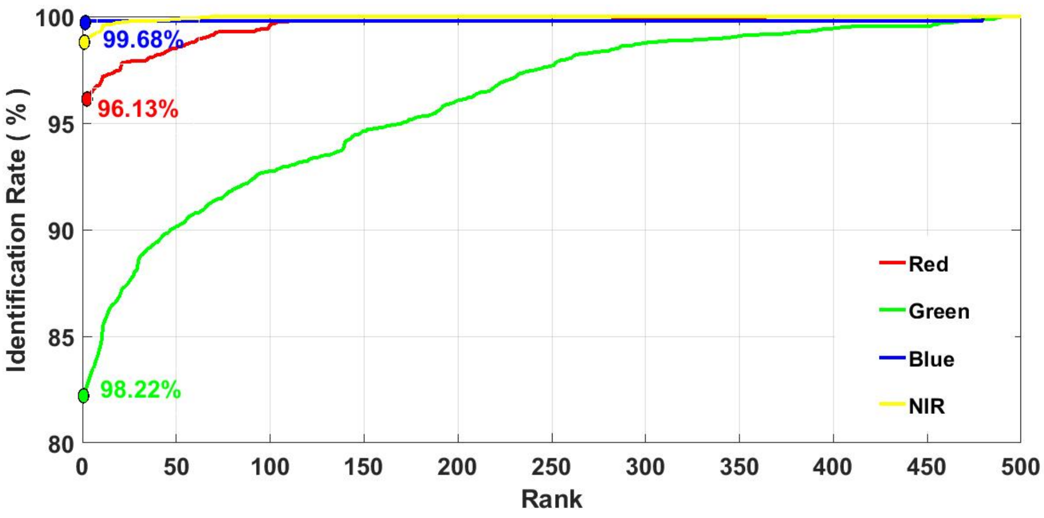


Figure III-5 unimodal system performance (CMC)

According to this figure, we observe that the BLUE band give the best **ROR** with a percentage of **99.68%,** but for the **RPR**, we remark that the **NIR** band gives the best **RPR** with a value of **69**.

III.5.2.3 Multimodal Application:

As we know, the orientation of multimodal biometric system is considered as one of the best solutions to improve the performance.

In this case, during our experimental study on a multimodal system of multi samples type, we proceed to do fusion tests.

In the first step, we have merged the BLUE, GREEN and RED bands, then, and in second, we will use all bands. Results are summarized in table (III-5) that gives the corresponding values of EER, the thresholdθ, the ROR and the RPR in the two multimodal cases.

Table III-5 : Results of EER, ROR and RPR for differnt multimodal bands

Modality	Open Mode		Closed Mode	
	EER (%)	Threshold θ_0	ROR	RPR
RED and GREEN and BLUE	**0.444**	**0.2245**	**100**	**01**
RED and GREEN and BLUE and NIR	**0.222**	**0.2361**	**100**	**01**

According to these results, the proposed multimodal cases present no enhancement in the open mode. The EER is bigger even the best band (NIR) is element of the second case.

However, a remarkable amelioration is achieved in close mode. Indeed, it shows a perfect results in the two multimodal cases with ROR=100% and RPR=1.

- **Graphical Interpretation**

The ROC curves that are mentioned below projects the values of the EER mentioned in table (III-5) on each intersection between these curves and the first bisector.

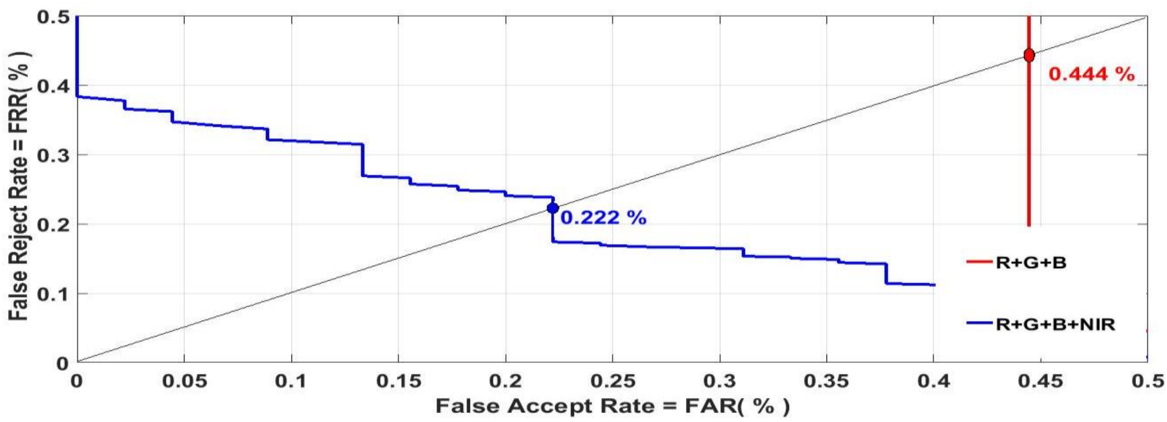


Figure III-6 multimodal System Performance

This figure allows us to classify the best fusion in the score level in a descending order like this:

- The fusion between the RED, Blue, GREEN and NIR bands, the Blue, the RED and the GREEN bands, which they gave the EER respectively (0.222 , 0.444).

The figure (III-7) shows the curves of accumulated scores (Cumulative Match Curve (CMC)) of the system associated to multi-spectral images application.

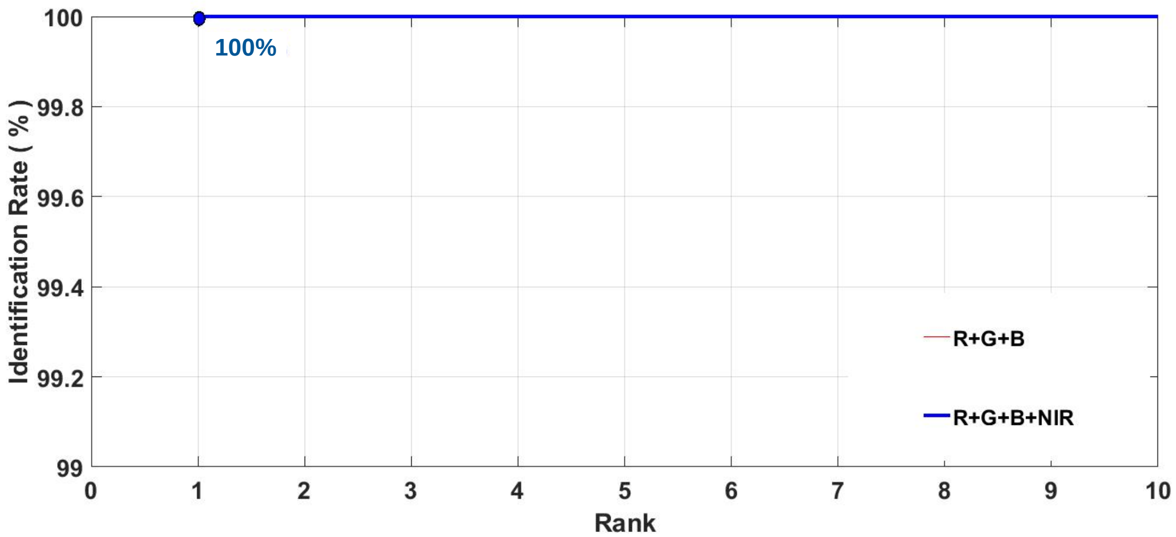


Fig. III.7: multimodal System Performance (CMC)

At the same time, it is clear that using a multimodal biometric system of multi samples type with a score fusion have permitted us to minimize the imperfections of a unimodal biometric system and enhance its performance in the closed mode.

GENERAL

CONCLUSION

General conclusion

In this work, we have presented an overview on biometric systems basics, the architecture and modules of a biometric system. In addition, we gave an insight into fusion levels and principle technics to evaluate biometric system performance measurements.

Our objective is to develop a robust algorithm to recognize person through their palmprint. For this purpose, we proposed a new approach to extract the discriminant features within a biometric image in order to be used in the proposed biometric identification system. Thus, qualified as universal approximator, Takagi-Sugeno fuzzy system is adopted to model the biometric image through optimization of error target function, in which Dai–Yuan conjugate gradient method was used to establish the proposed algorithm.

In order to evaluate our model, the Poly-U multispectral palmprint database is used. The obtained results show that the biometric system error in open mode (EER) is reduced especially when the NIR spectral band id used. The obtained results in unimodal case show relatively high performance. These results were perfectly enhanced, in closed mode, if multimodal biometric system is adopted. In this modest work and through fusion at score level, we achieved a reliable system with ROR of 100% and RPR enhanced to one when more biometric traits were combined. These results illustrate the important role of fusion in biometric field.

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