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Biometric System based on Artificial Neural Networks using Conjugate Gradient Optimization method

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We would also like to extend our sincere thanks to all the teachers who contributed to the end of our studies in particular.

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 this work.

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 father to my mother

To my brothers and sisters

To all my relatives in the **BELALEM** family

To all my masters and teachers: from primary to university

To all my dear friends and colleagues

BELAEM Elhadj Brahim

Dedication

I dedicate this work

To my dear mother and my father

To my sister and my brothers

And to all my family members, and more

Particularly To all my dear friends and Colleagues

And to all who taught me throughout my school life

HAFIANE Abdelhakim

Table of contents

List of abbreviations

ANN	Artificial Neural network
A/D	Analog to Digital
BNN	Biological Neural Networks
CCD	Charged Coupled Device
CMC	Cumulative Match Characteristic
DNA	Deoxyribo Neuclic Acid
EER	Equal Error Rate
FAR	False Acceptance Rate
FMR	False Match Rate
FNMR	False Non-Match Rate
FRR	False Rejection Rate
GAR	Genuine Accept Rate
CG	Conjugate Gradient
GCP	Gradient Conjugate preconditioned
GD	Gradient Descent
MSE	Mean Square Error
Nf	Number of Function
NIR	Near-infrared
N iter	Iteration number
R, G, B, N	Red, Green, Blue, NIR.
RPR	Rate Perfect Recognition
ROC	Receiver Operating Characteristics
ROR	Rank One Recognition

List of figures

Chapter I: Biometric system

Chapter II: Feature extraction based on Neural Network optimization

Chapter III: Experimental results and discussions

List of tables

General Introduction

General Introduction

" Biometric technologies are automated methods of verifying or recognizing the identity of a living person based on a physiological or behavioral characteristic " [1].

The human body is a sophisticated creation, full of every required sense for identification, verification and authentication and it is always on the verge to be understood in a greater extent. The security of information systems has become a very important area of research, in particular, designing a reliable, efficient and robust identification system is a priority task. Identification of the individual has become essential to ensure the safety of the systems and organizations. Faced with this growing demand, several biometric recognition methods have been proposed, palmprint recognition, facial recognition, fingerprint and iris recognition ... etc.

Over the last twenty years, artificial intelligence techniques, such as fuzzy logic, genetic algorithms and neural networks, have been increasingly applied to the control and identification of complex systems. The identification of these systems is today a field of research of interest major for the industry. It is often necessary to build models from real data (input-output), able to learn the dynamics of the system in question for the development of control laws.

Multimodal biometrics, which consists of combining several biometric systems, is being studied more and more. In fact, it makes it possible to reduce certain limitations of biometric systems, such as the impossibility of acquiring data from certain people or intentional fraud, while improving recognition performance. These advantages brought by multi-modality to "single-mode" biometric systems are obtained by merging several biometric systems.

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 artificial neural network system.

The artificial neural network is a technique widely used in the field of system control and the identification of industrial processes, and it's becoming an essential component of decoding assistance. Neural analysis is now reaching a degree of maturity that allows it to deal with a number of problems.

In our work, we will develop a biometric system where we will propose a feature extraction algorithm based on neural network optimization. So, this Dissertation is organized as the following:

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

In the second chapter, we will be talking about extracting features basing on neural network optimization by proposing a design method to find some optimal parameters using the artificial neural network.

In the last chapter, to evaluate the developed algorithm we will focus on the results of the application of the proposed method by applying on it a different human’s sample of palmprints.

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

Chapter I

Biometric system

I.1 Introduction

The security is the most significant problem in recent development in the communication technology systems. There are many available different identification technologies some of them have been in wide-spread commercial use for years. The most common person authentication or verification method is Biometric [2].

In the first chapter, we will introduce the biometric system and its different modalities, after that we will see the biometric system performance evaluation depending on the measurements. Besides, we will talk about multimodal biometric system passing by some problems of unimodal biometric system.

I.2 Biometrics

The word “Biometrics” is derived from two Greek words bio (life) and metric (to measure). Biometrics is a technology used to identify, analyze, and measure an individual’s physical and behavioral characteristics [3]. Biometrics is an effective technology for personnel identity authentication. It is a science which deals with verifying the identity of a person using his characteristics: physical (Fingerprint, Hand Geometry…etc), biological (DNA…etc) or behavioral (gait, voice signature…etc).

Therefore, it is a robust authentication method and it cannot be lost, forgotten or guessed by any imposter.

These characteristics are called biometric modalities that need to meet the following properties [4]:

- **Uniqueness**: It determines how uniquely a biometric system can recognize a user from a group of users.
- **Universality**: It indicates requirement for unique characteristics of each person in the world, which cannot be reproduced.
- **Permanence**: It indicates that a personal trait recorded needs to be constant in the database for a certain time period.
- **Measurability:** means how easily the data of the traits can be collected.
- **Performance:** It is the efficiency of system in terms of accuracy, speed, fault handling, and robustness.
- **Acceptability**: means that the Individuals in the target population that will utilize the application should be willing to present their biometric trait to the system [4].

I.3 Evolution of Biometrics

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. Fingerprinting is still used today.

In the 19th century, an Anthropologist named Alphonse Bertillion developed a method (named Bertillionage) of taking body measurements of persons to identify them [5].

He had realized that even if some features of human body are changed, such as length of hair, weight…etc, some physical traits of body remain unchanged such as length of fingers.

This method diminished quickly as it was found that the persons with same body measurements alone can be falsely taken as one. Subsequently, Richard Edward Henry from Scotland Yard developed a method for fingerprinting.

The idea of retinal identification was conceived by Dr. Carleton Simon and Dr. Isadore Goldstein in 1935 [6]. In 1976, a research and development effort was put in iris. The first commercial retina scanning system was made available in 1981.Iris recognition was invented by John Daugman in 1993 at Cambridge University.

Today, biometric has come up as an independent field of study with precise technologies of establishing personal identities.

I.4 Basic Components of a Biometric System

The main components in biometric system are illustrated in the figure (**I.1**):

- **Input Interface (Sensors)**

It is the sensing component of a biometrics system that converts human biological data into digital form. For example: a microphone in case of voice recognition systems.

- **Processing Unit**

The processing component is a microprocessor, Digital Signal Processor (DSP), or computer that processes the data captured from the sensors.

The processing of the biometric sample involves:

- Sample image enhancement.
- Sample image normalization.
- Feature extraction.
- Comparison of the biometric sample with all stored samples in database.

- **Database Store**

The database stores the enrolled sample, which is recalled to perform a match at the time of authentication. For identification, there can be any memory from Random Access

Memory. For verification, a removable storage element like a contact or contactless smart card is used.

➢ **Output Interface**

The output interface communicates the decision of the biometric system to enable the access to the user.

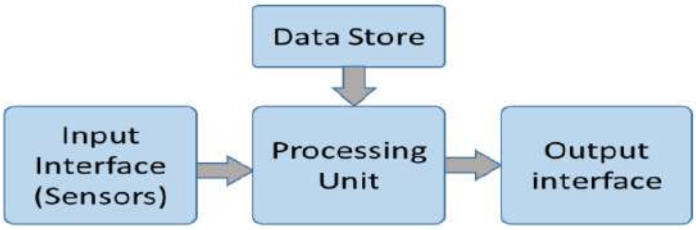


Figure I.1: Components of a Biometric System.

I.5 General Working of a Biometric System

There are four general steps that biometric system takes to perform identification and verification:

- Acquire live sample from candidate (using sensors).
- Extract prominent features from sample (using processing unit).
- Compare live sample with samples stored in database (using algorithms).
- Present the decision (Accept or reject the candidate).

The biometric sample is acquired from candidate user. The prominent features are extracted from the sample and it is then compared with all the samples stored in the database. When the input sample matches with one of the samples in the database, the biometric system allows the person to access the resources, otherwise prohibits.

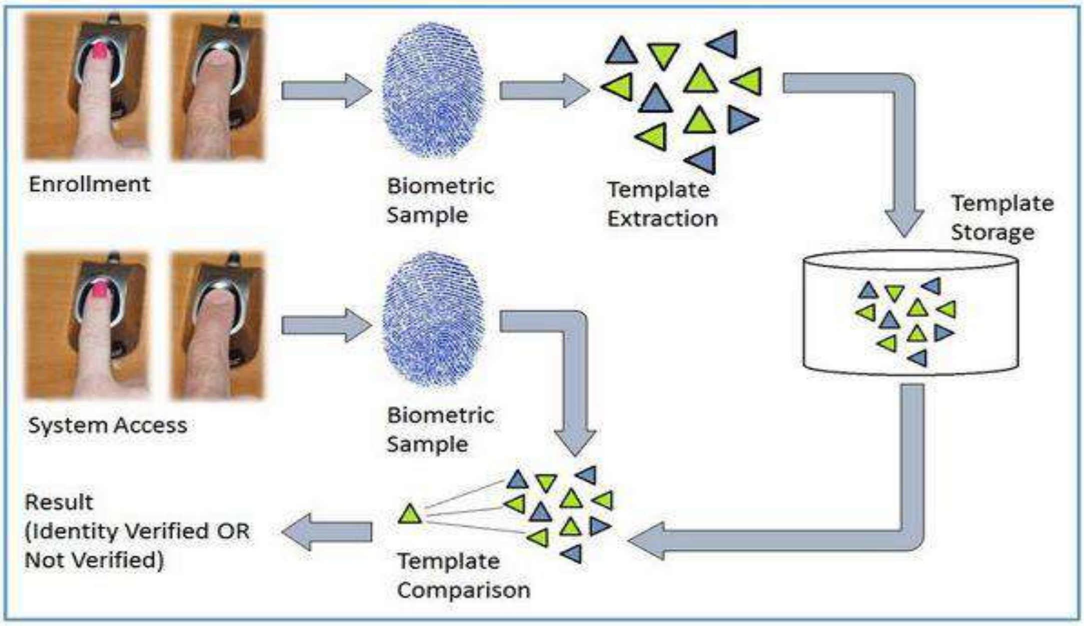


Figure I. 2: Example about how biometric system works.

I.6 Types of Biometric Modalities

Biometric technology is sophisticated, cleverer, super sensitive and put in place to help protect companies and individuals.

Most importantly, it is impossible to steal or duplicate as the name suggests biometrics works on biological characteristics of an individual.

There are various traits present in humans, which can be used as biometrics modalities. The biometric modalities fall under three types: morphological, behavioral and biological (see figure **I.3**).

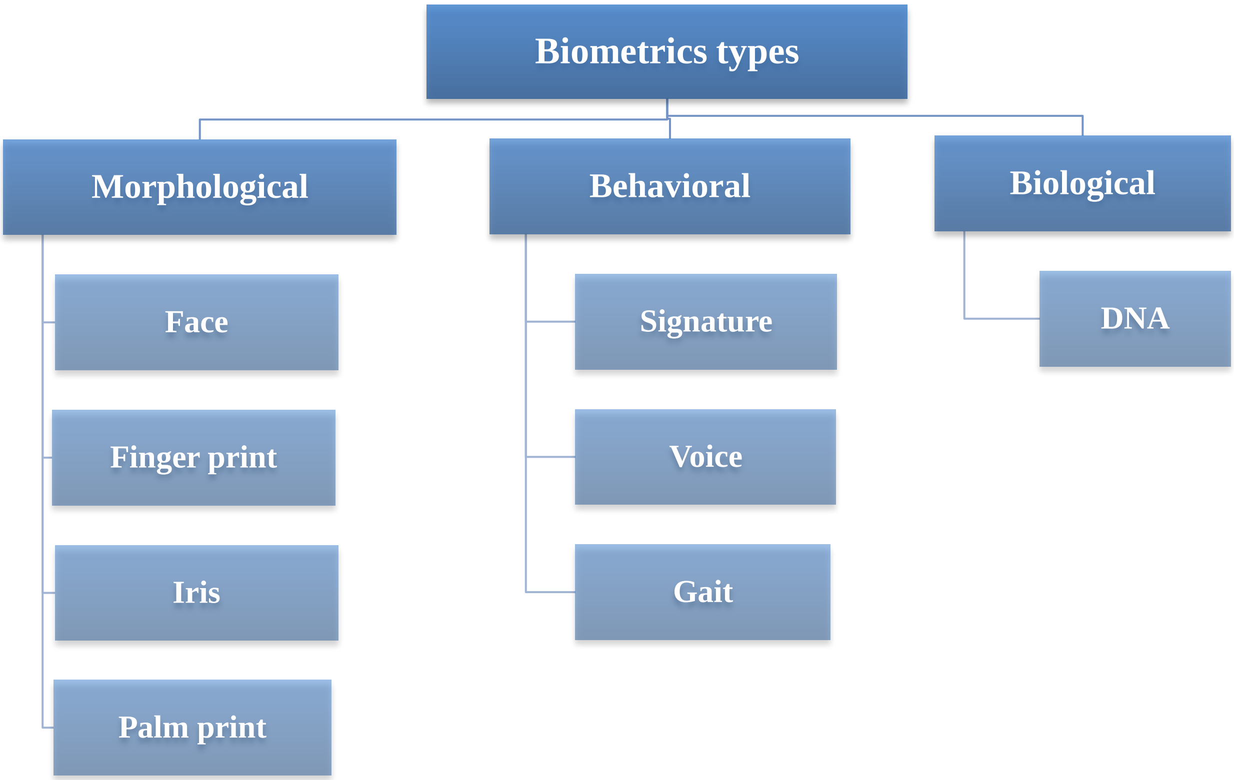


Figure I. 3: The main types of biometrics modalities.

I.6.1 Morphological modalities

a) Face Recognition

Uses distinct facial features to create authorization. These features include upper outlines of the eye socket, areas around the cheek bones, the sides of the mouth and the location of the nose and eyes.

Traditional systems use algorithms to identify facial features by landmarks and compare relative size or shape of eyes, nose, cheekbones, and jaw, however three-dimensional recognition improves accuracy by using three-dimensional sensors to recognize distinct facial features (see figure **I.4**).

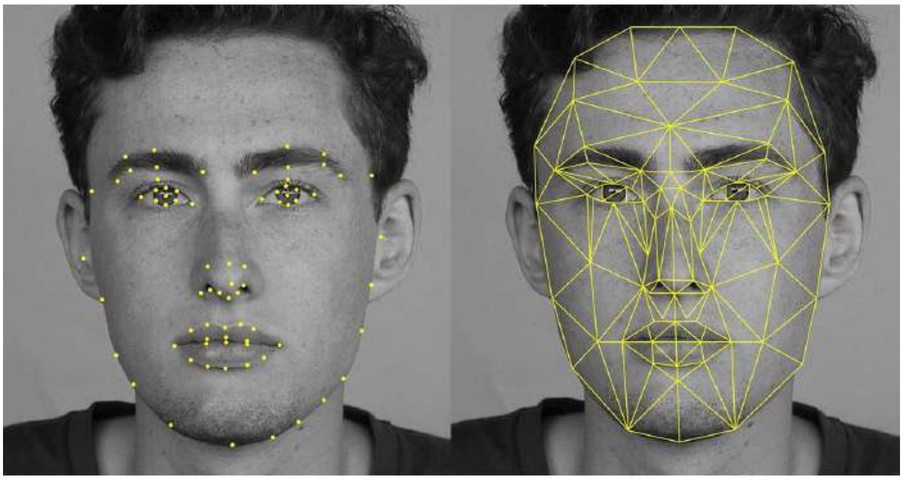


Figure I.4: Sample biometric traits: face

b) Finger print

It is the most successful and popular method for person identification because everyone's print is unique 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 (see figure I.4).

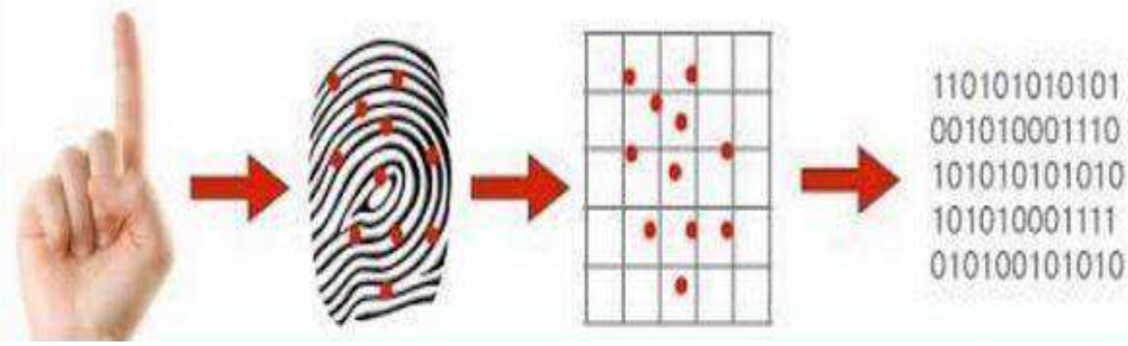


Figure I. 5: Example of finger print biometric traits.

c) Iris recognition

Iris recognition works on the basis of iris pattern in human eye. The iris is the pigmented elastic tissue that has adjustable circular opening in center. It controls the diameter of pupil. In adult humans, the texture of iris is stable throughout their lives. The iris patterns of left and right eyes are different. The iris patterns and colors change from person to person.

It involves taking the picture of iris with a capable camera, storing it, and comparing the same with the candidate eyes using mathematical algorithms (see figure **I.6**).

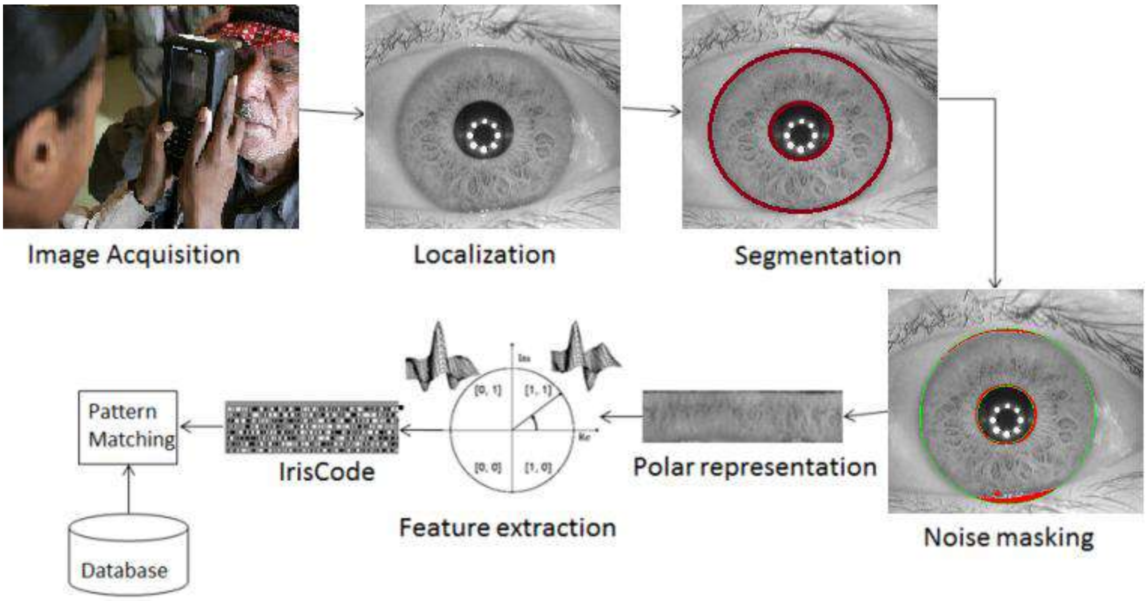


Figure I. 6: Sample biometric traits: Iris.

d) Palm print

The palms of the human hands contain pattern of ridges and valleys much like the fingerprints [8]. The area of the palm is much larger than the area of a finger and as a result palm prints are expected to be even more distinctive than the fingerprints. Since palm print scanners need to capture a large area they are bulkier and more expensive than the fingerprint sensors. Human palms also contain additional distinctive features such as principal lines and wrinkles that can be captured even with a lower resolution scanner, which would be cheaper (see figure **I.7**).

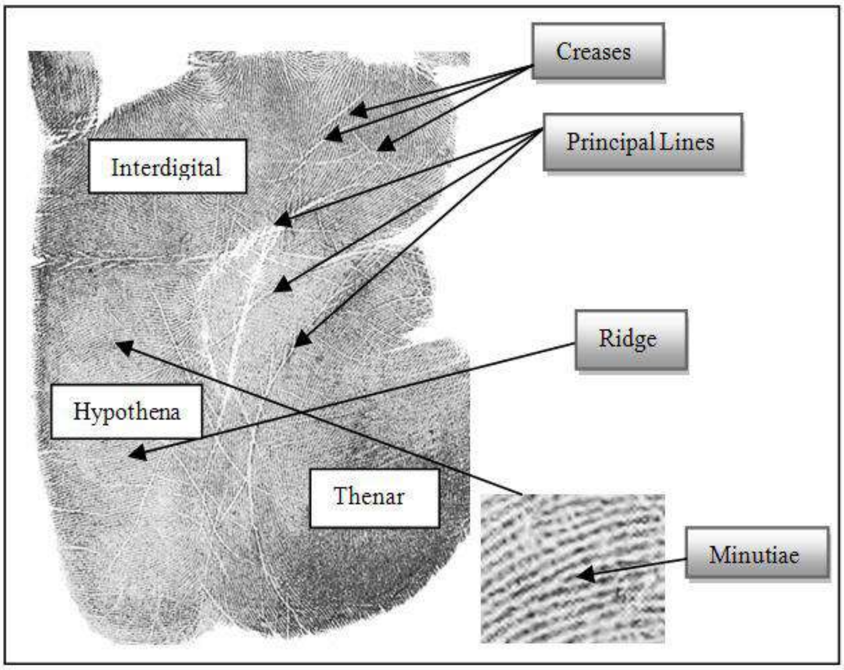


Figure I. 7: Sample biometric traits: palm print.

I.6.2 Behavioral modalities

a) Signature

Is a form of authentication based on an individual's signature. The final image or signature isn't what is recorded but the process leading up to it instead things like pressure differences, pen up and down, spatial coordinate x and y, azimuth, inclination, and writing speed are measured at various points in the signature, Normally forgers have a challenge recreating all of these factors which helps strengthen this type of authentication more secure (see figure **I.8**).

Figure I. 8: 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 (see figure **I.9**).

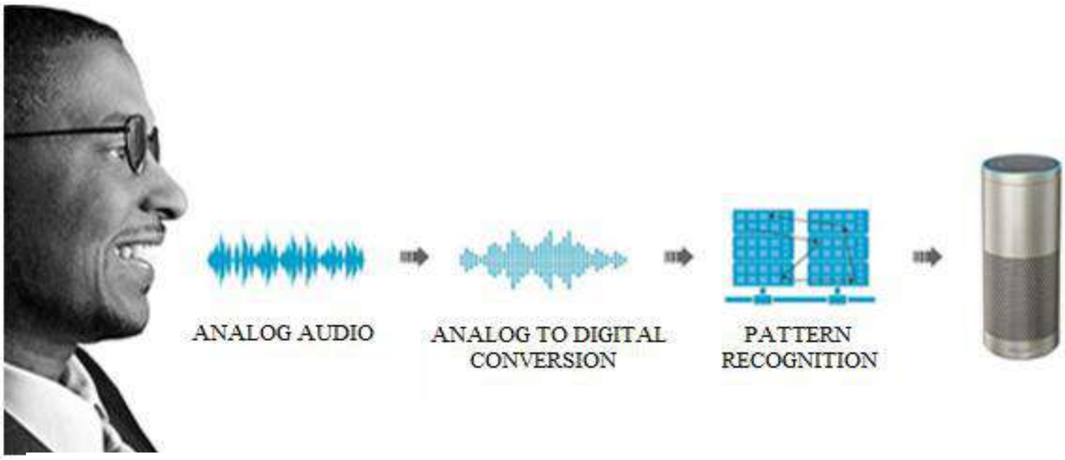


Figure I. 9: Sample biometric traits: voice.

c) Gait

Gait is the manner of a person's walking. People show different traits while walking such as body posture, distance between two feet while walking, swaying…etc. which help to recognize them uniquely (see figure **I.10**).

A gait recognition based on the analyzing the video images of candidate's walk. The sample of candidate's walk cycle is recorded by Video. The sample is then analyzed for position of joints such as knees and ankles, and the angles made between them while walking.

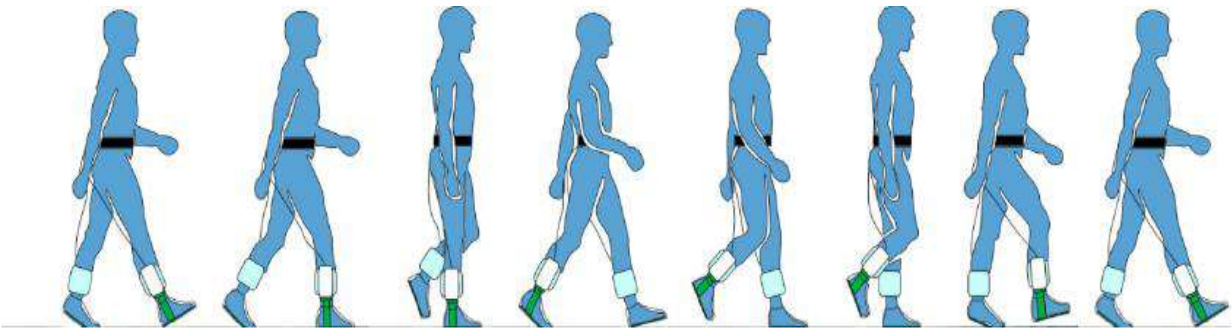


Figure I. 10: Sample biometric traits: gait.

I.6.3 Biological modalities

a) DNA

Deoxyribo **N**euclic **A**cid (DNA) is the genetic material found in humans. Every human barring identical twins, is uniquely identifiable by the traits found in their DNA, which is located in the nucleus of the cell. There are number of sources from which DNA patterns can be collected such as blood, saliva, nails, hair.

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.

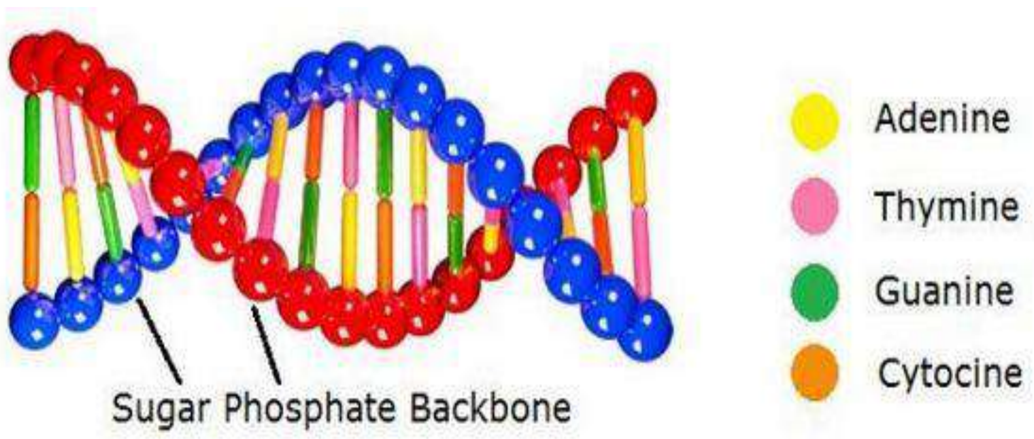


Figure I. 11: Sample biometric traits: DNA.

I.7 Function mode

Each biometric system has two phases of execution: Enrollment and Testing (verification or identification).

I.7.1 Enrollment mode

It is the first phase of any biometric system, the stage in which a user is registered in the system for the first time and where one or more biometric modalities are captured and stored in a database as illustrated in the figure **I.12**.

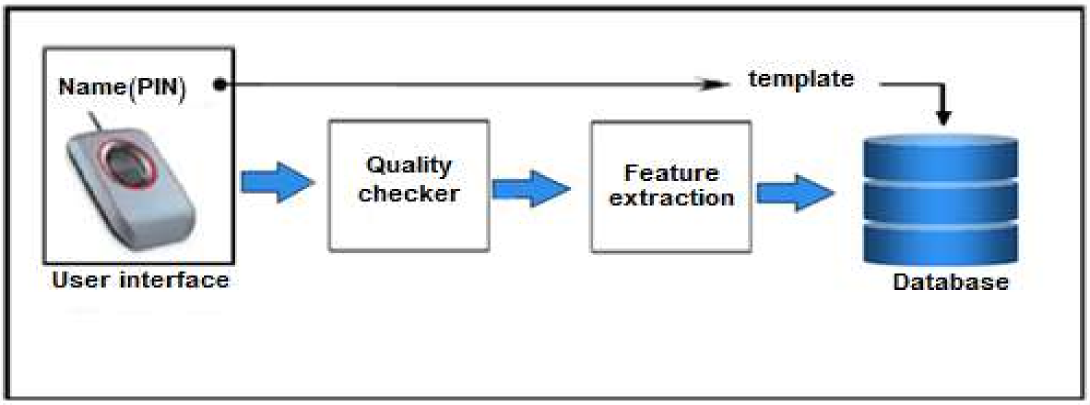


Figure I. 12: Enrolment of person in the biometric system.

I.7.2 Verification mode

The verification, also called authentication, is the confirmation of the validity of an identity declared by the comparison between a biometric template associated with a verification identity (proposed by the user) and a biometric enrollment template. During the check the system answers the question "Am I the person I claim to be?" by yes or no. So the system must verify that the identity of the person is the one proposed by the user, so just compare it with only one of the models in the database.(see figure **I.13**). It’s a one-to-one comparison (1: 1).

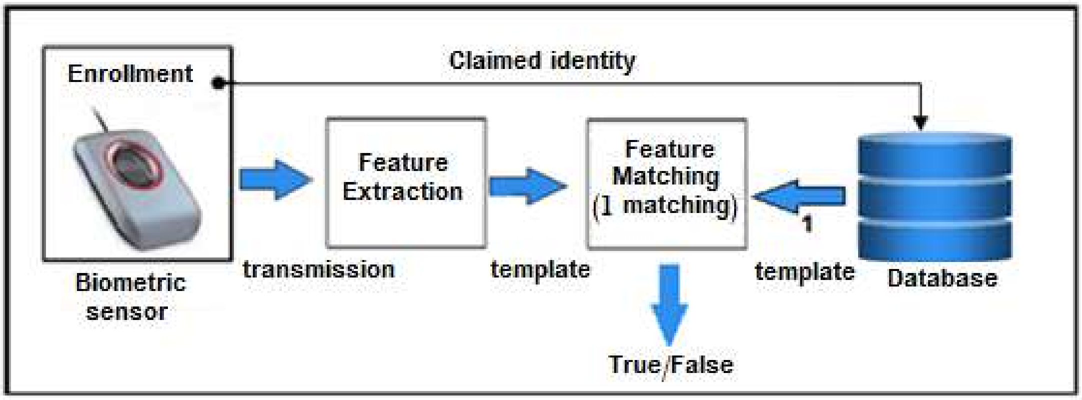


Figure I. 13: Verification of person in the biometric system.

I.7.3 Identification mode

The system must guess the identity of the person. He answers a question such as "Who am I?" Accept if the user has a template in the database or reject it if the user does not have a template in the database. In this mode, the system compares the measured signal with the different models contained in the database during the enrollment phase as shown in figure **I.14**, it's a one-to-many comparison (1: N).

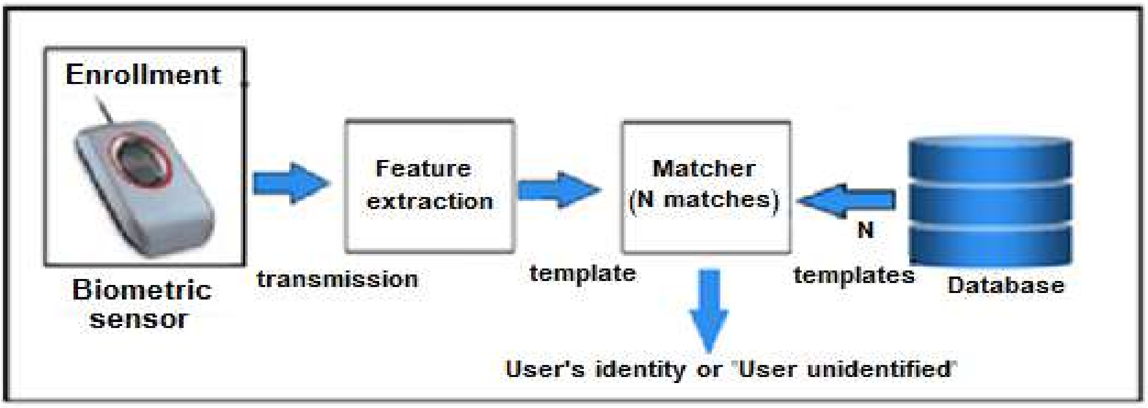


Figure I. 14: Identification of person in the biometric system.

At this stage we can describe two types:

- **Closed-set identification**: users need to be enrolled into a biometric system and verified for access to be granted.
- **Open-set identification:** identifying users who may are not be enrolled in the system.

I.8 Performance evaluation of Biometric system

The performance of a biometric system can be measured primarily using these 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 [9].
- **Effort:** deployed by the user when entering biometric measures.

I.9 Performance Measures in Biometric System

Biometric identifiers are the distinctive, measurable characteristics used to label and describe individuals. The performance measurements of biometrics-based systems are mainly defined by the security level. The following measures are used as performance metrics for biometric systems.

I.9.1 False Acceptance Rate (FAR) or False Match Rate (FMR)

Is a statistic used to measure biometric performance when operating in the verification task. The percentage of times a system produces a false accept, which occurs when an individual is incorrectly matched to another individual's existing biometric [10]. It is defined as:

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

I.9.2 False Rejection Rate (FRR) or False Non-Match Rate (FNMR)

Is a statistic used to measure biometric performance when operating in the verification task. The percentage of times the system produces a false reject.

A false reject occurs when an individual is not matched to his/her own existing biometric template [11]. 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.15**). 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 distribution are separated or with narrow overlapping region.

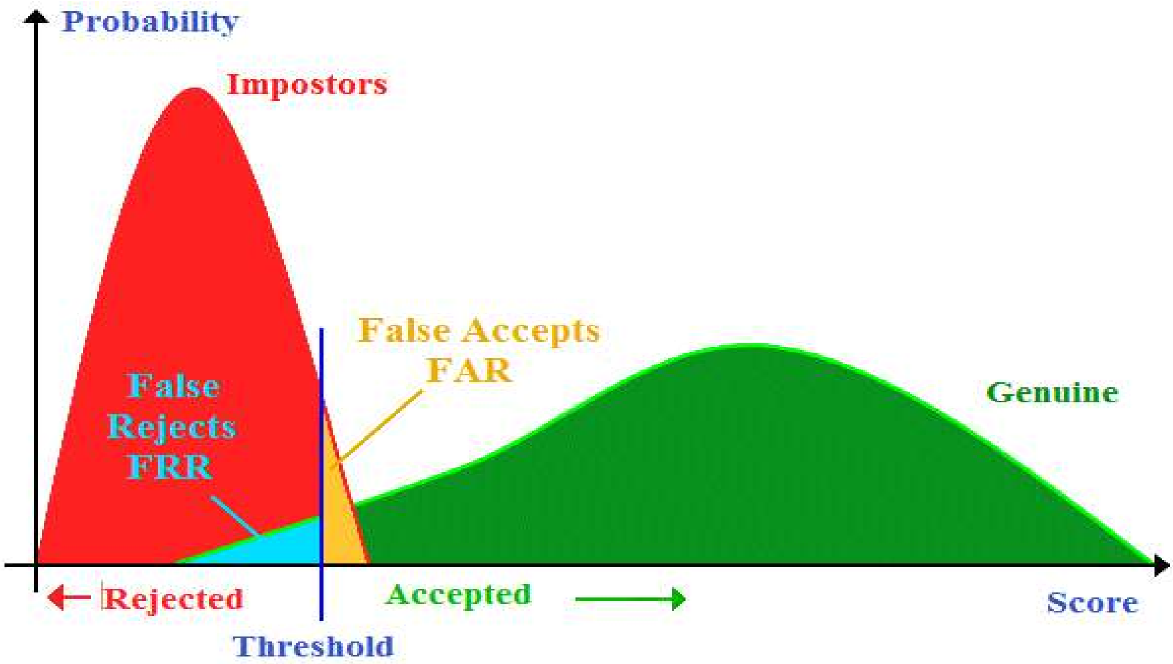


Figure I.15: FAR and FRR curves.

I.9.3 Equal Error Rate (EER)

Is the rate at which both acceptance and rejection errors are equal. The value of the EER can be easily obtained from the ROC curve. The EER is a quick way to compare the accuracy of devices with different ROC curves. In general, the device with the lowest EER is the most accurate (figure **I.16**).

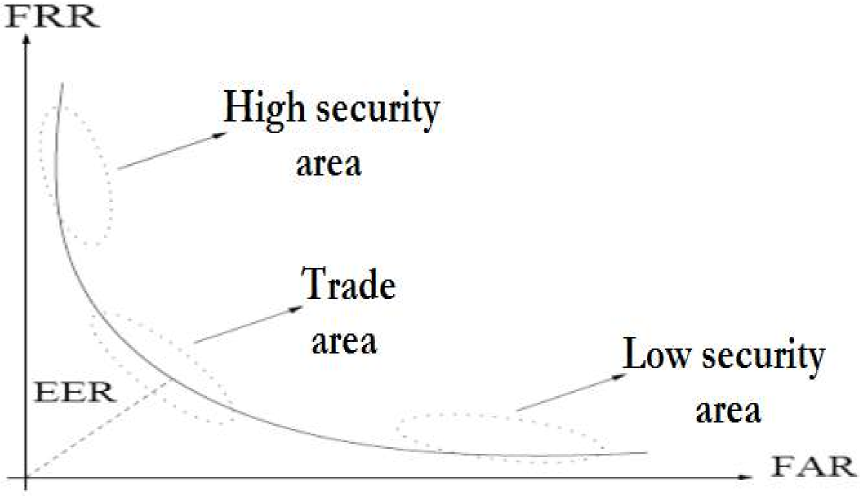


Figure I. 16: Example of EER curves.

I.9.4 Receiver Operating Characteristics (ROC)

The ROC plot is a graphical representation of the performance of the verification system for different values. Equal Error Rate or EER corresponds to the FAR - FRR point, that is to stay graphically at the intersection of the ROC curve with the first bisector. This rate is frequently used to give an overview of the performance of a biometric system. The threshold must therefore be adjusted according to the targeted application: high security, low security or trade-off between them (see figure **I.17**).

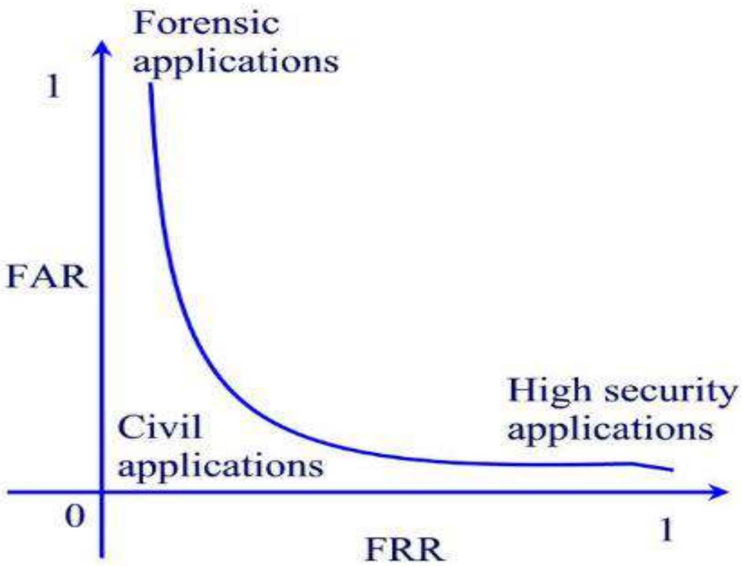


Figure I. 17: Example of ROC curves.

I.9.5 Genuine Accept Rate (GAR)

This is defined as a percentage of genuine users accepted by the system. It is given by:

$$GAR = 1 - FRR \qquad (I.3)$$

I.9.6 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:

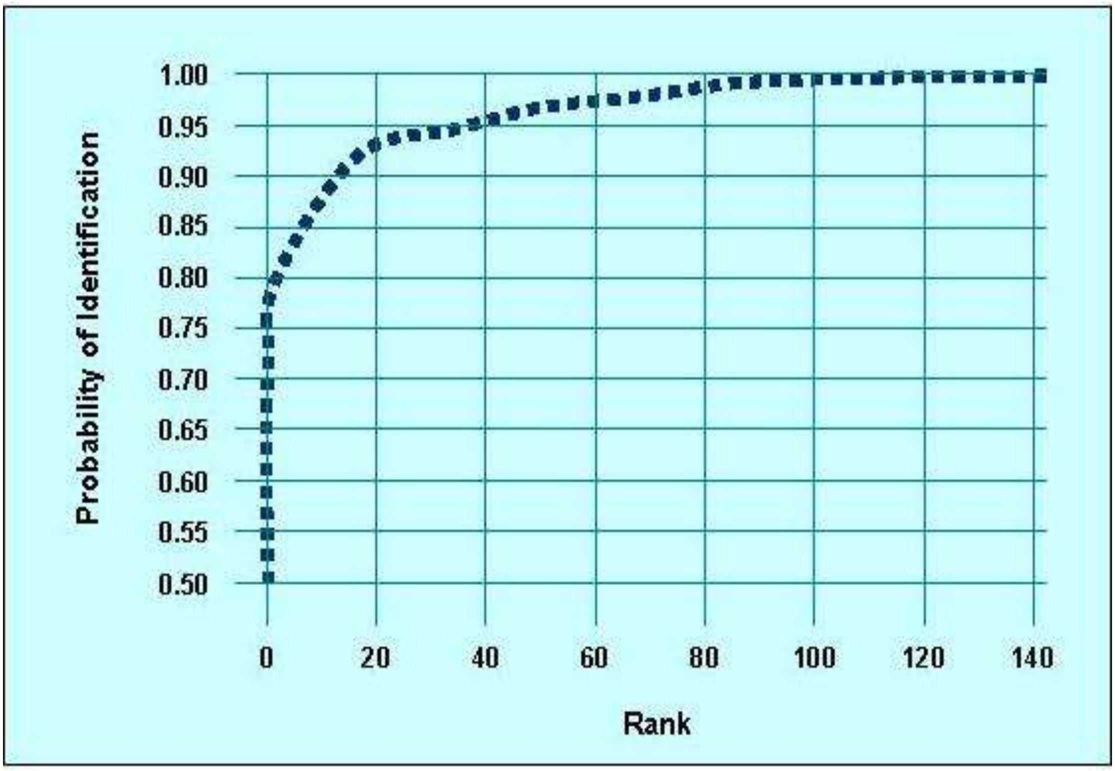


Figure I. 18: Example of CMC curve.

I.10 Multibiometric system categories

I.10.1 Unimodal biometric systems

Unimodal biometric systems perform person recognition based on a single source of biometric information, but suffer from problems like noisy sensor data, non-universality, lack of distinctiveness of the biometric trait, and spoof attacks [12].

I.10.2 Multimodal biometric systems

Multibiometric systems seek to alleviate some of these drawbacks by providing multiple evidences of the same identity. These systems help achieve an increase in performance that may not be possible using a single biometric indicator. Further, multibiometric systems provide anti-spoofing measures by making it difficult for an intruder to spoof multiple biometric traits simultaneously. This system can be classified into one of the following categories (see figure **I.19**) [13]:

1) **Multi-sensor systems:** A single biometric modality is acquired by using a number of sensors.

2) **Multi-algorithm systems:** A single biometric input is processed with different feature extraction algorithms in order to create templates with different information content.

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 [14].

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.

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 [14]. 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).

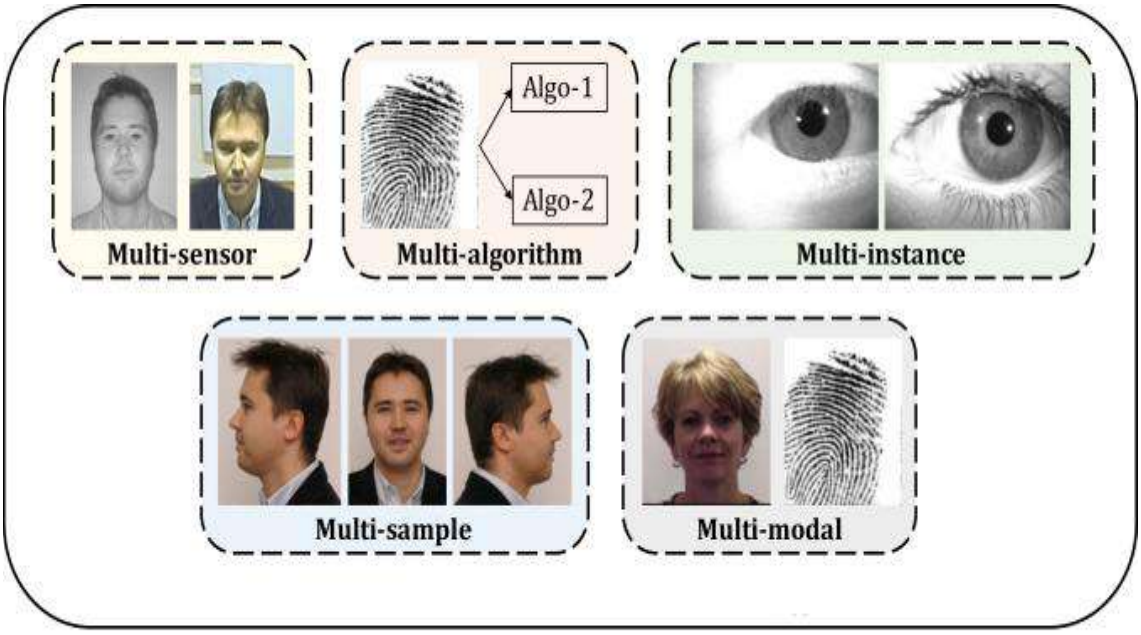


Figure I. 19: Sources of Fusion in a Multibiometric system.

I.11 Fusion Levels

Multimodal biometric system extracts information from different biometric source and obtains the fuse information for authentication. Combining information or evidence generated by multiple biometric sources is known as information fusion.

The main aim of information fusion is to get detailed information which obtains from different sources; however different fusion techniques can used for biometric information fusion for example: simple Sum, Multiplication, Minimum, and Weighted Sum.

The literature shows that biometric information fusion is categorized in to two main types; fusion before matching that is (pre-mapping fusion) or fusion after matching that is (post-mapping fusion). Feature level fusion is types of pre-mapping while score level, and decision level fusion are type of post- mapping [15].

Here short descriptions about all fusion types are given below:

I.11.1 Feature level fusion

Feature level fusion shown in figure (**I.20**), refers to combining the different feature sets extracted from multiple biometric modalities into a single feature vector [8].

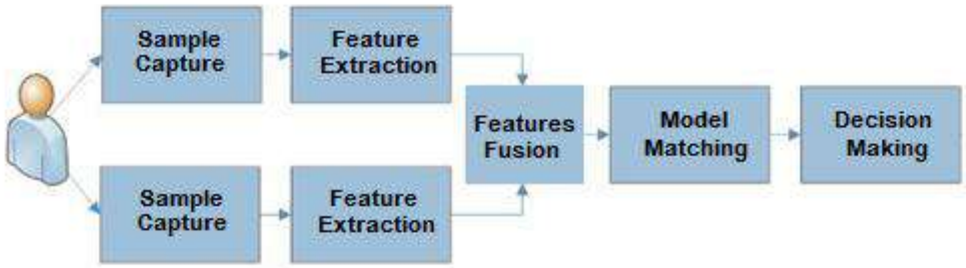


Figure I. 20: Feature level Fusion.

I.11.2 Score level fusion

The scores generated by multiple classifiers pertaining to different modalities are combined (see figure **I.21**).

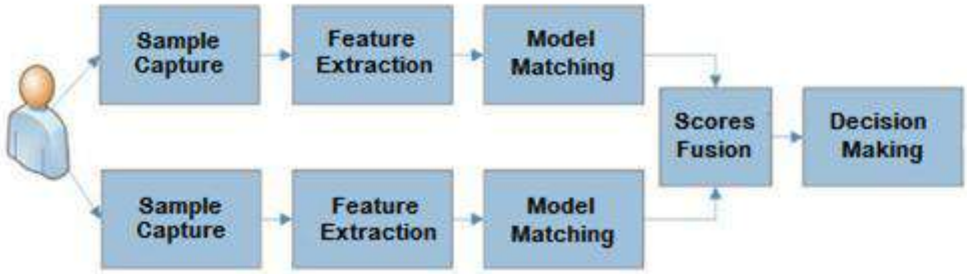


Figure I. 21: Score level Fusion.

I.11.3 Decision level fusion

In this case the final outputs of multiple classifiers are consolidated via techniques such as majority voting (see figure **I.22**).

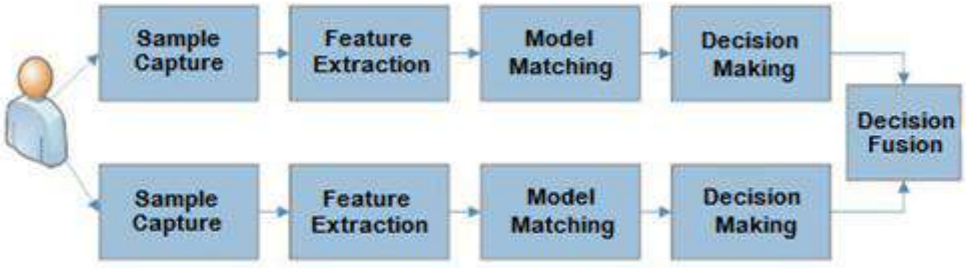


Figure I. 22: Decision level Fusion.

I.12 Conclusion

In this chapter, we presented some definitions and notions related to the biometrics systems and his modalities.We discovered the multimodal biometric system and the fusion operation.

In the second chapter, we will focus on the procedure to construct feature vector through modeling the biometric image by a Neural Networks.

Chapter II

Feature extraction based on Neural Networks optimization

II.1 Introduction

It is necessary to meditate 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 of more complex calculations in a split of second, while unable completely to do the most basic of human activities unless they are represented numerically [16].

These observations pushed Dr. Warren McCulloch and Dr. Walter Pitts in 1943 to create a computational model for artificial neural networks based on mathematics and algorithms called threshold logic [17].

In this chapter, we will propose a design method to find some optimal feature vector. For that, we will use the artificial neural networks as modeling tool of biometric modality. Unknown parameters will be identified through gradient optimization method.

In this chapter we will see the artificial neural networks and his main useful propriety followed by the modality image representation as nonlinear function. After that, we will examine the optimization problem and it's resolution.

II.2 Neural Networks

II.2.1 Biological Neural Networks

A neuron (nerve cell) is a cell that carries electrical impulses [18], where they are connected to one another. They do not touch and instead form tiny gaps called synapses. These gaps can be chemical synapses or electrical synapses and pass the signal from one neuron to the next. The most important components of the neuron (figure **II.1**):

- Dendrite: It receives signals from other neurons.
- Soma (cell body): It sums all the incoming signals to generate input.
- Axon: When the sum reaches a threshold value, neuron fires and the signal travels down the axon to the other neurons.
- Synapses: The point of interconnection of one neuron with other neurons. The amount of signal transmitted depends upon the strength (synaptic weights) of the connections.

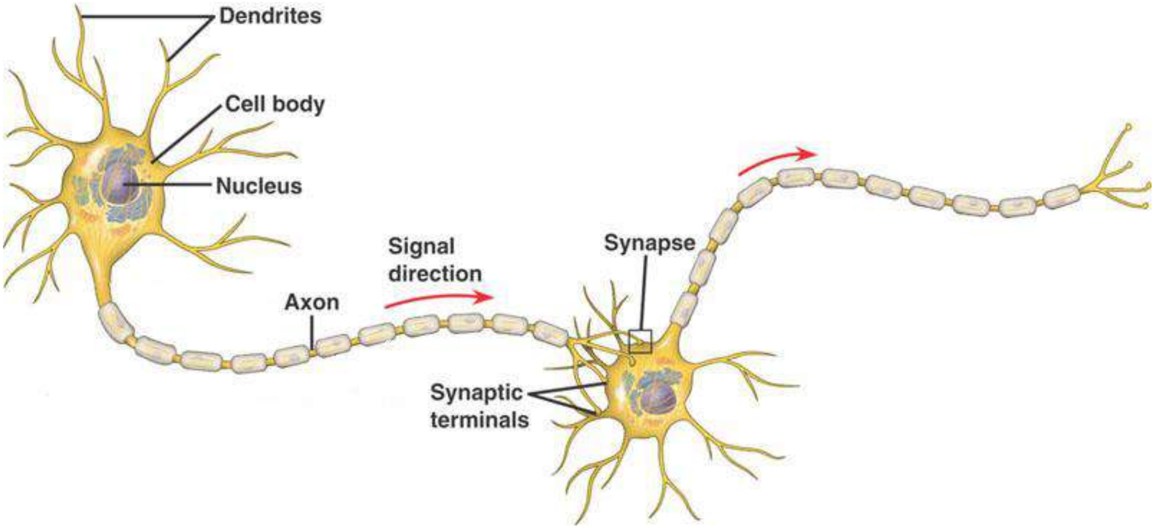


Figure II. 1: Biological neural network model.

II.2.2 Artificial Neural Network

An Artificial Neural Network (ANN) is a computational model that is inspired by the biological neural networks that constitute human brains [19] .The neural network itself is not an algorithm, but rather a framework for many different machine learning algorithms to work together and process complex data inputs [20] Such systems "learn" to perform tasks by considering examples, generally without being programmed with any task-specific rules.

An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal from one artificial neuron to another. An artificial neuron that receives a signal can process it and then signal additional artificial neurons connected to it.

II.2.3 Artificial Neuron Network Structure

In the table II.1 we will see the components of Artificial Neural Network (ANN) and their equivalents in the Biological Neural Network (BNN).

Table II. 1: BNN and ANN components.

BNN	ANN
Dendrites	Input layer
Cell Body	Hidden layer
Axon terminals	Output layer

The artificial neural network is often divided in three main parts constitute:

- Input layer: the training observations are fed through these neurons.
- Hidden layer: intermediate layers between input and output which help Neural Network learn the complicated relationships involved.
- Output layer: the final output is extracted from previous two layers.

In general, a formal neuron is a processing element with n inputs x_1, x_2, ..., x_i, ...,x_n (which are the external inputs or outputs of other neurons) and one or more outputs. Its processing consists in carrying out at its output $\mathbf{y_j}$ the result of a threshold function (also called the activation function) of the weighted and bias sum (figure **II.2**).

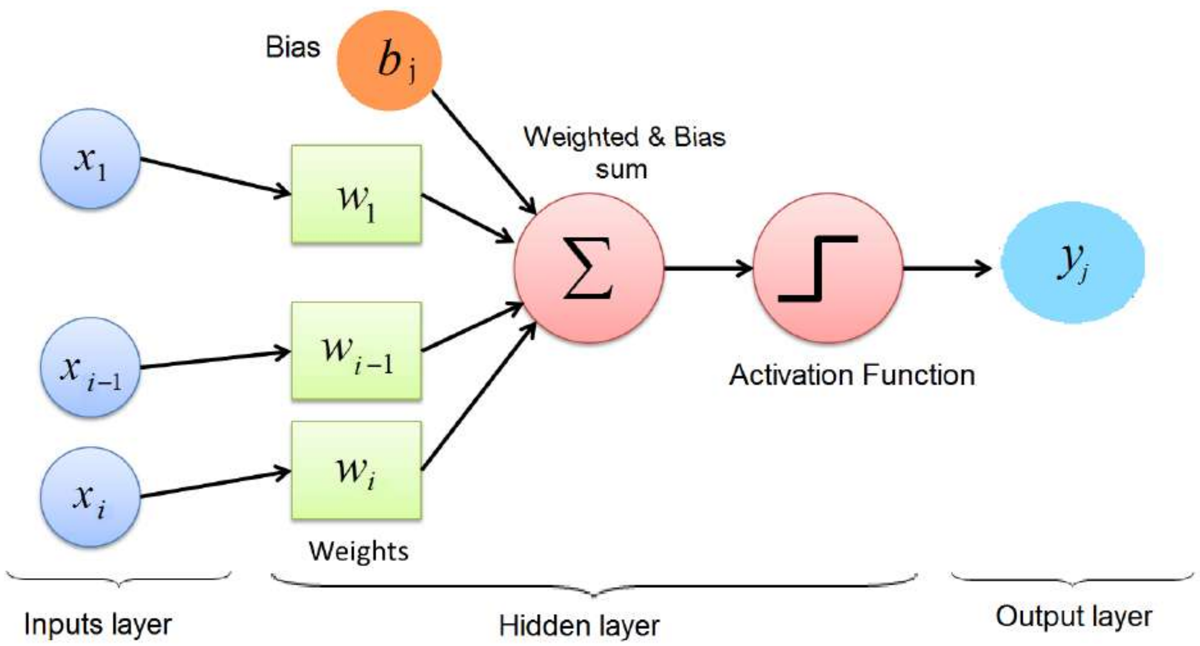


Figure II. 2: Artificial neural network Structure .

We mention the most famous neural network architecture types:

1. Single hidden layer: consists of three layers (input and, output layer and hidden layer) (see figure **II.3.a**).
2. Multi hidden layer: consists of more than three layers (input and, output layer and hidden layers) (see figure **II.3.b**).

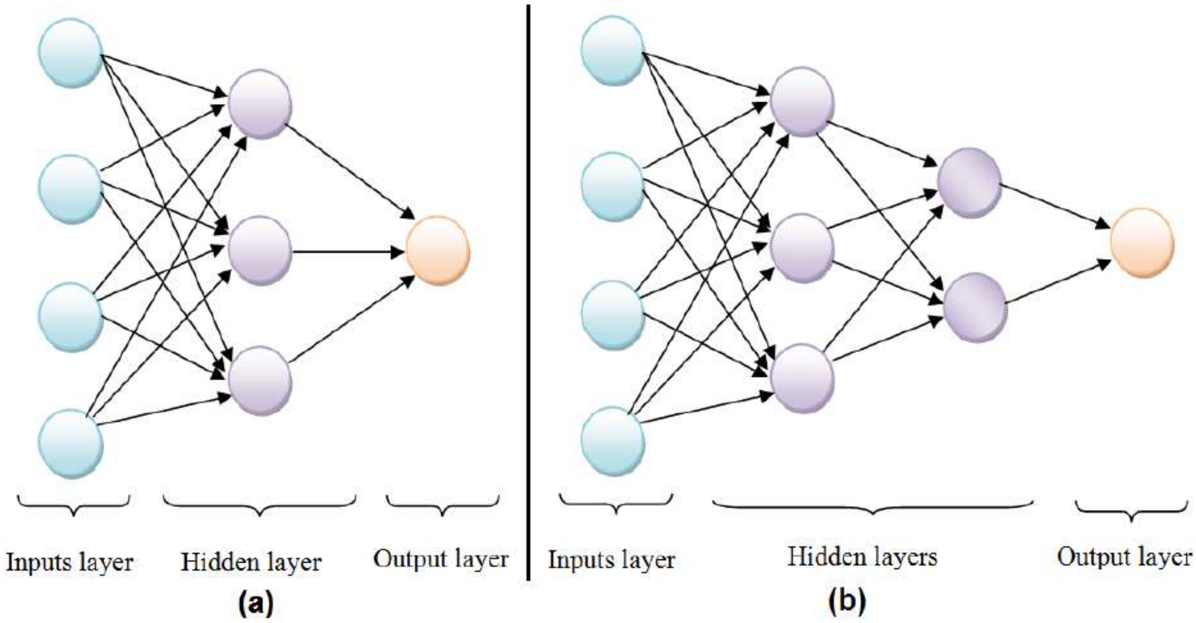


Figure II. 3: Neural network architecture: (a) Single hidden layer, (b) Multi hidden layer.

II.2.4 Mathematical formulation of ANN

In the case of Single Perseptron the output can be expressed by the following mathematical formulation [21]:

$$y_j = f_j(\sum_{i=1}^{n} W_{ij} \,.\, X_i + b_{ij}) \qquad \text{(II.1)}$$

with:

X_i : The input. W_{ij}: The weights.

y_j: The output of neuron j. b_{ij}: The bias.

$f_j(x)$: Activation function. n : Number of inputs

But in case of one hidden layer network and linear output layer function the mathematical formulation of output will be : $Y = \sum_{j=1}^{N} \theta_j y_j$ (II.2)

Y: The output. θ_j: The weights.

y_j: The output of neural j. N: Number of neurons.

Bias: is an external parameter of the neuron (weight) [22].

Activation function: is the function in an artificial neuron that delivers an output based on inputs. It is used to determine the output of neural network like yes or no. It maps the resulting values in between 0 to 1 or -1 to 1 …etc. (depending upon the function).

The Activation Functions can be basically divided into 2 types:

1) Linear Activation Function.
2) Non-linear Activation Functions.

The following functions are some examples of activation functions:

1) Unit step (threshold) Function

$$f(x) = \begin{cases} 0, & x < 0 \\ 1, & x \geq 0 \end{cases} \quad \text{(II.3)}$$

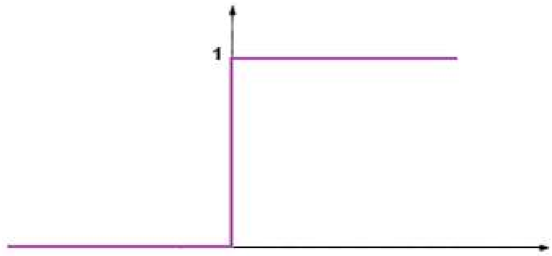


Figure II. 4: Unit step function.

2) Sigmoid Function:

$$f(x) = \frac{1}{1+e^{-x}} \quad \text{(II.4)}$$

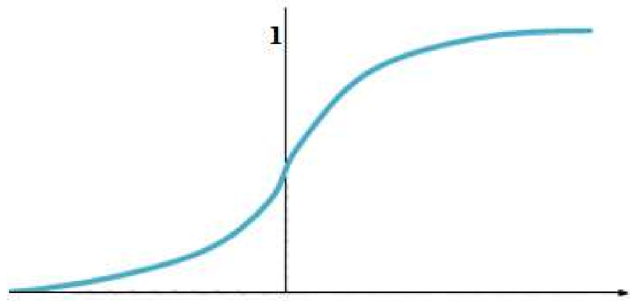


Figure II. 5: Sigmoid function.

3) Linear Function:

$$f(x) = Ax \quad \text{(II.5)}$$

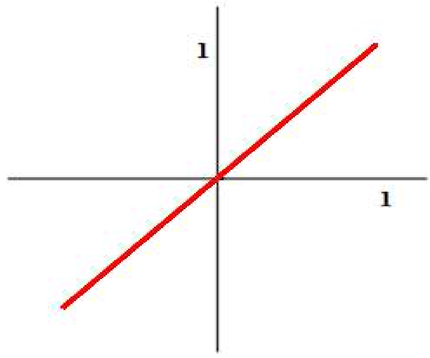


Figure II. 6: Linear function.

4) Gaussian function:

It is defined by two parameters $\{\sigma, m\}$:

$$f(x) = \exp\left(-\frac{(x-m)^2}{\sigma^2}\right) \quad \text{(II.6)}$$

σ: The width of the Gaussian function.

$\boldsymbol{m}$: The center of the receptive field.

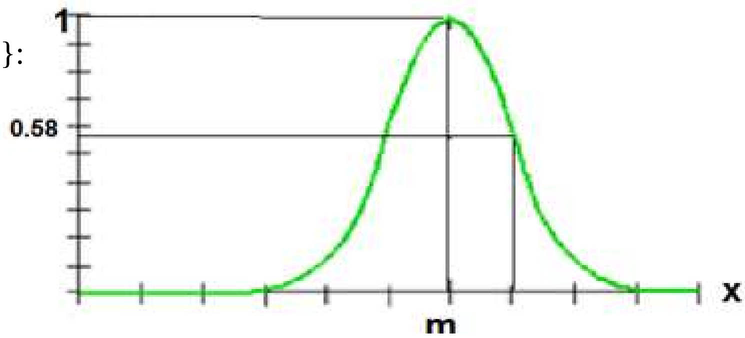


Figure II. 7: Gaussian function.

II.2.5 Characteristics of Artificial Neural Networks

- **Learning:** Network with "no knowledge" can be trained with set of paired input output data to give desired outputs for known inputs. Learning from examples.
- **Generalization:** Produce best output according to learned examples if a different vector is input into network.
- **Non linearity:** Cope with nonlinear data and environment.
- **Fault Tolerance:** Good response even if input data is slightly incorrect.
- **Robustness:** Whole system can still perform well even if some neurons "go wrong".

II.2.6 Learning Algorithm

The process of change in weights in order to have a better response from the network, the change is reached when the network is stabilized, it is often impossible to decide a prior values of the weights of connections of a network for a given application. At the end the weights are fixed.

There are two types of learning:

- **Supervised learning:** is the most used. We present to the network of inputs and at the same time the outputs that we would like for this input. The network must then be reconfigured. That is to say, calculate its weight so that the output it gives corresponds to the desired output.
- **Unsupervised Learning:** When we work without using predefined labels. The unsupervised machine learning algorithms act without human guidance.

II.3 Digital images

Digital images are images manipulated by the computer (represented by a series of bits) [23], whose surface is divided into fixed-size elements called pixels, each having as characteristic a level of gray or colors taken from the corresponding location in the actual image. The digitization of an image is the conversion thereof from its analog state to a digital image represented by a two-dimensional matrix of numerical values I (x, y) as shown in figure (**II.8**), where ***x*** and ***y*** are Cartesian coordinates of a point of the image and I (x, y) the intensity level.

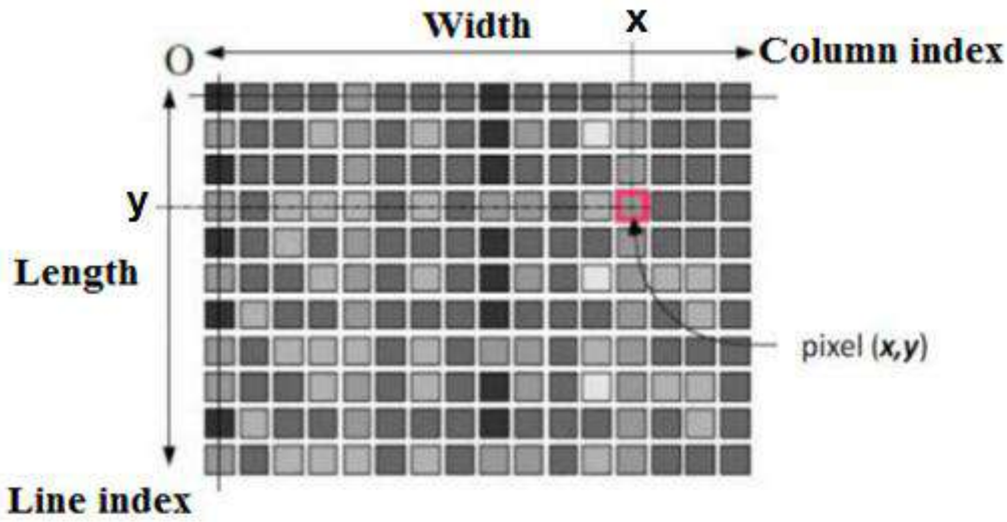


Figure II. 8: Digital image representation.

II.4 Grayscale images (Monochrome)

The gray level is the value of the light intensity at a point. The color of the pixel can take values ranging from black to white through a finite number of intermediate levels. So to represent grayscale images, for example in figure (**II.9**), each pixel of the image can be assigned a value corresponding to the amount of light returned [24].

The number of gray levels depends on the number of bits used to describe the "color" of each pixel in the image. The greater the number, the more levels are possible [25].

Figure II. 9: Image grayscale.

The artificial neural networks can be divided into 2 basic types:

1. Linearly parameterized neural networks (LPNN): in which the adjustable parameters appear linearly.
2. Multilayer neural networks (MNN): in which the adjustable parameters appear nonlinearly.

II.5 Universal approximation

We find an important property that makes artificial neural network popular in modeling and identification problems in several research works [26] .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 artificial neural network to approximate any nonlinear smooth functions. In other words, we can write:

$$| \mathrm{I} - \hat{\mathrm{I}} | \leq \varepsilon_{max} \tag{II.7}$$

Where $\hat{\mathrm{I}}$ the approximate function of the original one **I** and ε_{max} is the maximum error of approximation.

Let us consider that we have networks with two-layer in which the hidden layer performs a fixed nonlinear transformation with no adjustable parameters, i.e., the input space is mapped into a new space. The output layer then combines the outputs in the latter space linearly.

Therefore, they belong to a class of linearly parameterized neural networks (LPNN), and can be simply expressed as:

$$\hat{\mathrm{I}}(x) = Y = \theta^{T} S(X). \tag{II.8}$$

With the input vector $x \in \mathrm{IR}^n$, weight vector $\theta \in \mathrm{IR}^L$, weight number L, and basis function vector: $S(X) = [S_1(X), S_2(X), S_3(X), \dots, S_L(X)]^T \in \mathrm{IR}^L$.

This is the same idea used by The Radial Basis Function RBF networks provided that S(X) is a continuous positive function on [0,∞), and its first derivative is completely monotonic. in this work we use the Gaussian function because it's commonly used RBF [24], which have the form :

$$S_j(X) = \exp\left(-\sum_{i=1}^{n}\left(\frac{\|x_{ij}-\mu_{ij}\|}{\sigma_{ij}}\right)^2\right) \tag{II.9}$$

With: σ_{ij}: The widths of the Gaussian function.

$\mu_{ij} = [\mu_{i1}, \mu_{i2}, \dots, \mu_{in}]^T$: The center of the receptive field.

From the equation (II.1) if we put: $W_{ij} = \frac{1}{\sigma_{ij}}$ and $b_{ij} = \frac{\mu_{ij}}{\sigma_{ij}}$ we will find that:

$$y_j = f_j(\sum_{i=1}^{n}\left(\frac{\|x_i-\mu_j\|}{\sigma_j}\right)^2) \tag{II.10}$$

The figure (**II.10**) illustrates the previous mathematical development with two neurons (j) (j+1). it is known as Radial Basis Function (RBF) network .

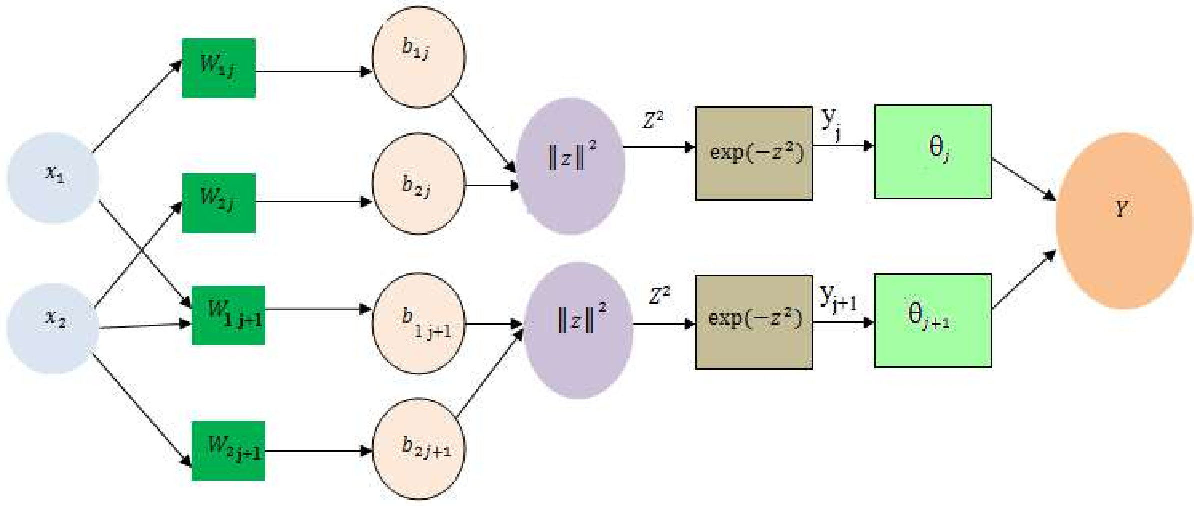


Figure II. 10: Radial Basis Function (RBF) networks

In next section we will exploit the linear formulation of the ANN output given by equation II.8 to develop our biometric image modeling.

II.5.1 Quadratic problem formulation

We consider a function associated with a biometric image given by $\mathrm{I}(x,y)$ and the approximated function $\hat{\mathrm{I}}(x,y) = S^T(x,y).\theta$, we propose firstly to choose the vector θ as the feature vector of the biometric image and secondly to identify this vector through minimization of Mean Square Error function (MSE). This last will reflect the approximation error of the biometric image by the ANN. Let us consider the following criterion function (MSE):

$$E^2 = \frac{1}{\mathrm{Np}} \sum_{x,y} \left(\mathrm{I}(x,y) - \hat{\mathrm{I}}(x,y)\right)^2 \qquad \text{(II.11)}$$

Where Np is the number of pixels contained in the image. This criterion is the average of the square approximation errors over the whole image also called Mean Square Error (MSE). This last equation is written:

$$E^2 = \frac{1}{\mathrm{Np}} \sum_{x,y} (\mathrm{I}(x,y) - S^T(x,y).\theta)^2 \qquad \text{(II.12)}$$

After development, we obtain:

$$E^2 = \frac{1}{\mathrm{Np}} \sum_{x,y} \theta^T S^T(x,y) S^T(x,y).\theta - \frac{1}{\mathrm{Np}} \sum_{x,y} 2\,\mathrm{I}(x,y)\, S^T(x,y).\theta + \frac{1}{\mathrm{Np}} \sum_{x,y} \left(\mathrm{I}(x,y)\right)^2$$

In matrix form, we rewrite the MSE as: $E^2 = \frac{1}{2}\theta^T A\,\theta + B^T\,\theta + c$ (II.13)

Where the matrix A, the vector b and the scalar **c** are given by:

$$A = 2\sum_{x,y}\frac{S(x,y).S^T(x,y)}{Np} \quad \text{(II.14)}$$

$$B^T = -\sum_{x,y}\frac{2.I(x,y)S^T(x,y)}{Np} \quad \text{(II.15)}$$

$$c = \sum_{x,y}\frac{I^2(x_i,y_j)}{Np} \quad \text{(II.16)}$$

The criterion E^2 is now reformulated as a quadratic function, the literature offers us several optimization algorithms. The best known are those derived from the so-called Gradient method [27]. There are many deterministic (or exact) methods for solving certain types of optimization problems and for obtaining the optimal solution of the problem in a reasonable time.

These methods require that the criterion to be minimized has a certain number of characteristics such as convexity, continuity or differentiability.

II.5.2 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 :

$$E^2 = \frac{1}{2}\theta^T A\,\theta + B^T\,\theta + c \quad \text{(II. 17)}$$

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 $\boldsymbol{E}$and $\boldsymbol{B}$ is its gradient. By convention, any constants contained in the objective function are left out of the general formulation .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.11**) illustrate an example of the solution convergence to the optimum.

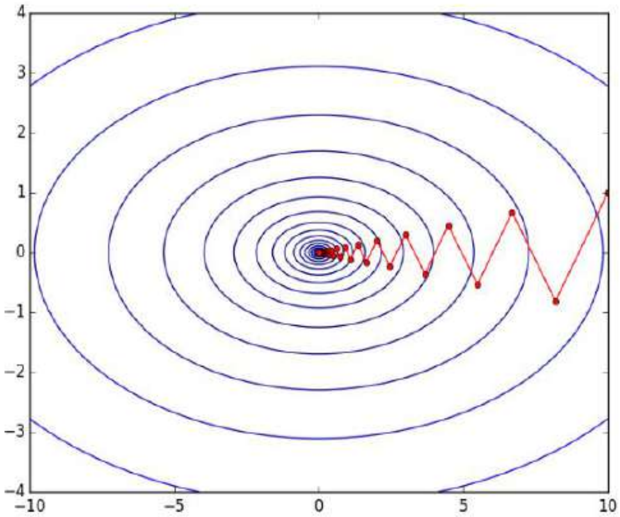


Figure II. 11:Optimization of a quadratic function

II.6 Gradient Method

In optimization, gradient method is an algorithm to solve problems of the form:

$$min\ (E^2) \tag{II.18}$$

With the search directions defined by the gradient of the function at the current point. An examples of gradient method are the gradient descent and the conjugate gradient.

II.6.1 Gradient Descent method

Gradient descent or steepest descent method is a way of optimization to find a local minimum of a function. The way it works is we start with an initial guess of the solution and we take the gradient of the function at that point. We step the solution in the negative direction of the gradient and we repeat the process. The algorithm will eventually converge where the gradient is zero (which corresponds to a local minimum). In gradient descent we minimize a function f(x), by using the update rule:

$$\theta_{t+1} = \theta_t - \alpha.\nabla E^2(\theta_t) \tag{II.19}$$

II.6.2 Conjugate Gradient method

Conjugate gradient method research **n** conjugate directions such that progress made in one direction does not affect progress made in the other directions thus we only need to search in n directions to find the optimal point [28].

The method proceeds by generating vector sequences of iterates, residuals corresponding to the iterates, and search directions used in updating the iterates and residuals.

The main reason which take us use this method in our memory that it depends a fewer and effective iterations for solving then Gradient descent (figure (**II. 12**)).

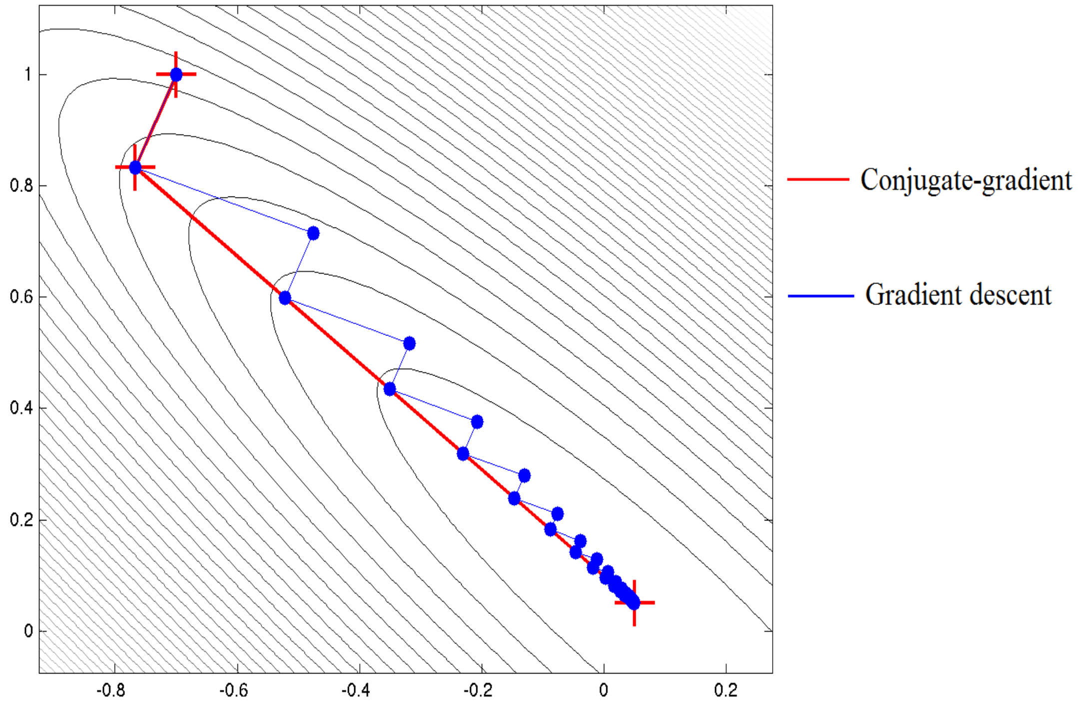


Figure II. 12: Comparison between gradient descent and conjugate-gradient methods.

So from the equation (III.14) we have the gradient is ∇E^2 (x) = (A$\theta - b$). The minimum of this functional is reached for the optimal point θ^* ∈ IR^n which cancels ∇E^2 (x), thus verifying A θ^*= b.

The iterates to $\theta_i$are updated in each iteration by a multiple α_i of the search direction vector d_i:

$$\theta_{i+1} = \theta_i + \alpha_i d_i \quad \text{(II.20)}$$

Correspondingly the residuals $r_i = b - A\theta_i$ are updated as $r_{i+1} = r_i - \alpha_i \, A \, d_i$ (II.21)

The search directions are updated using the residuals $d_{i+1} = r_{i+1} + \beta_i d_i$ (II.22)

Knowing that the adjustment coefficient $\beta_i = \frac{\boldsymbol{r_{i+1}^T r_{i+1}}}{\boldsymbol{r_i^T r_i}}$ (II.23) (Fletcher-Reeves formula) is calculated where $(d_{i+1}, Ad_i = 0)$,we say that the directions d_i and d_{i+1} are conjugate for A, ensures that r_i and r_{i+1} are orthogonal ($r_i \perp r_{i+1}$).

The gradient method algorithm can be summarized as follows [29]:

Algorithme III.1

Let θ_0 be the starting point (given) and ε the precision (fixed) given

Put $r_0 = A\theta_0 - b = -d_0$

For i =0 to n

$$\alpha_i = -\frac{r_i^T\, d_i}{d_i^T\, A\, d_i} \quad \text{(Optimal step)}$$

$\theta_{i+1} = \theta_i + \alpha_i d_i$ (Advancement with D_i direction of descent)

$r_{i+1} \leftarrow r_i + \alpha_i\, A\, d_i$ (Gradient iterative calculation)

$$\beta_i = \frac{(r_{i+1}^T\, r_{i+1})}{(r_i^T r_i)} \quad \text{(Parameter ensuring } (d_{i+1}, d_i) = 0)$$

$d_{\,i+1} = -r_{i+1} + \beta_i\, d_i$ (Iterative calculation of the descent direction)

If $r_{i+1}^T r_i^T$ < ε stop.

If the algorithm (GC) can be considered as an exact method (Convergence is provided in n iterations at most), it is generally used as an iterative method expecting it to converge more quickly.

To accelerate the speed of convergence, one can precondition the linear system [29]. The idea here is to multiply the initial system by a matrix **C**, So-called precondition, and solve the new system (C A θ = C b) by the classical (GC).

In a strict sense, for the GC application, the system matrix must be symmetrical and positively positive, an unsecured case even if the matrix **C** is symmetrical and positively positive (the result of two identical positive positive matrices). This observation leads us to the following algebraic treatments to find a simple formula for the algorithm (GCP).

Let U ∈ $IR^{n\times n}$ be an invertible matrix and $\boldsymbol{z} = \boldsymbol{U\,\theta}$ a change of variable. so the linear system will be : $A^*z = b^*$ of matrix $A^* = U^{-T}AU^{-1}$symmetric, positive definite, and second member $b^* = U^{-T}b$. We can apply the (GC) for this system, and the main quantities to be calculated become (see algorithm III.1):

$$r_0 = U^{-T}AU^{-1}z^0 - U^{-T}b \quad \Leftrightarrow \quad r_0U^T = A\,\theta_0 - b = R_0$$

$$r_{i+1} = r_i + \alpha_i\, U^{-T}AU^{-1}\, d_i \quad \Leftrightarrow \quad R_{i+1} = R_i + \alpha_i\, AU^{-1}\, d_i = R_i + \alpha_i\, A\, D_i$$

$$d_0 = -r_0 \quad \Leftrightarrow \quad D_0 = U^{-T}U^{-1}R_0 = -CR_0$$

$$\alpha_i = -\frac{r_i^T\, d_i}{d_i^T\, A\, d_i} \quad \Leftrightarrow \quad \alpha_i = -\frac{U^{-T}R_i^T\, UD_i}{UD_i^T\, U^{-T}AU^{-1}\, UD_i} = -\frac{R_i^T\, D_i}{D_i^T\, A\, D_i}$$

$$z_{i+1} \leftarrow z_i + \alpha_i\, d_i \quad \Leftrightarrow \quad \theta_{i+1} \leftarrow \theta_i + \alpha_i\, D_i$$

$$\beta_i = \frac{(r_{i+1}^T\, r_{i+1})}{(r_i^T r_i)} \qquad \Leftrightarrow \qquad \beta_i = \frac{(U^{-T}R_{i+1}^T\, U^{-T}R_{i+1})}{(U^{-T}R_i^T U^{-T}R_i)}$$

$$d_{\,i+1} = -\, r_{i+1} + \beta_i\, d_i \qquad \Leftrightarrow \qquad D_{\,i+1} = -\, CR_{i+1} + \beta_i\, D_i$$

Note that the matrix $C = U^{-T}U^{-1}$ is symmetric, positive definite, and that it is the only matrix intervening in the preceding expressions (the matrix U is used just to build the algorithm). If we denote (a, b) C = (Ca, b) the scalar product induced by C on IR^n, the algorithm (GCP) is written in the following form [29]:

Algorithme III.2

The conjugate gradient preconditioned by a positive definite symmetric matrix C:

We have $\theta_0 \in IR^n$, ε , C given

Put $R_0 = A\theta_0 - b = -d_0$, $D_0 = -CR_0$

For i =0 to n

$\alpha_i = -\frac{R_i^T\, D_i}{D_i^T\, A\, D_i}$

$\theta_{i+1} \leftarrow \theta_i + \alpha_i\, D_i$ (Advancement with D_i direction of descent)

$R_{i+1} = R_i + \alpha_i\, A\, D_i$ (Gradient iterative calculation)

$\beta_i = \frac{(U^{-T}R_{i+1}^T\, U^{-T}R_{i+1})C}{(U^{-T}R_i^T U^{-T}R_i)C}$ (Parameter ensuring (d_{i+1}, d_i) = 0)

$D_{\,i+1} = -\, CR_{i+1} + \beta_i\, D_i$ (Iterative calculation of the descent direction)

If $\left(R_{i+1}^T R_i^T\right) C$ < ε stop.

It is clear from what precedes that the "ideal" choice for matrix C would be $C = A^{-1}$, the inverse of matrix A, in this case, obviously, the use of the conjugate gradient method would become not necessary. In practice, whenever Precondition matrix "close" to A^{-1}, the convergence of the algorithm will be better. At the same time, the matrix C must be the simplest and broadest as possible, which imposes as the easiest choice.

II.7 Conclusion

As a conclusion for this chapter, we had formulated the identification of biometric images as a quadratic problem optimization. The conjugate gradient precondition method was presented to find the best solution that minimizes the approximation error of the biometric image.

We suggest considering the optimal vector, determined by the conjugate gradient method precondition as the feature vector of biometric modality.

Chapter III

Experimental results and discussions

III.1 Introduction

Palmprint is a variety of features that are distinguishes from other modalities. They pushed us to consider it as an appropriate choice for our experimental study which will be exposed in this chapter. Thus, we will first introduce palm print recognition. Then we will examine a single characteristic of the target database of our application. The next section will be dedicated to the development of experimental protocol, and the interpretation of different evaluation parameters.

III.2 Palmprint recognition

The palmprint is the inside of the hand (part not visible when the hand is closed) from the wrist to the finger roots, it's 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**).

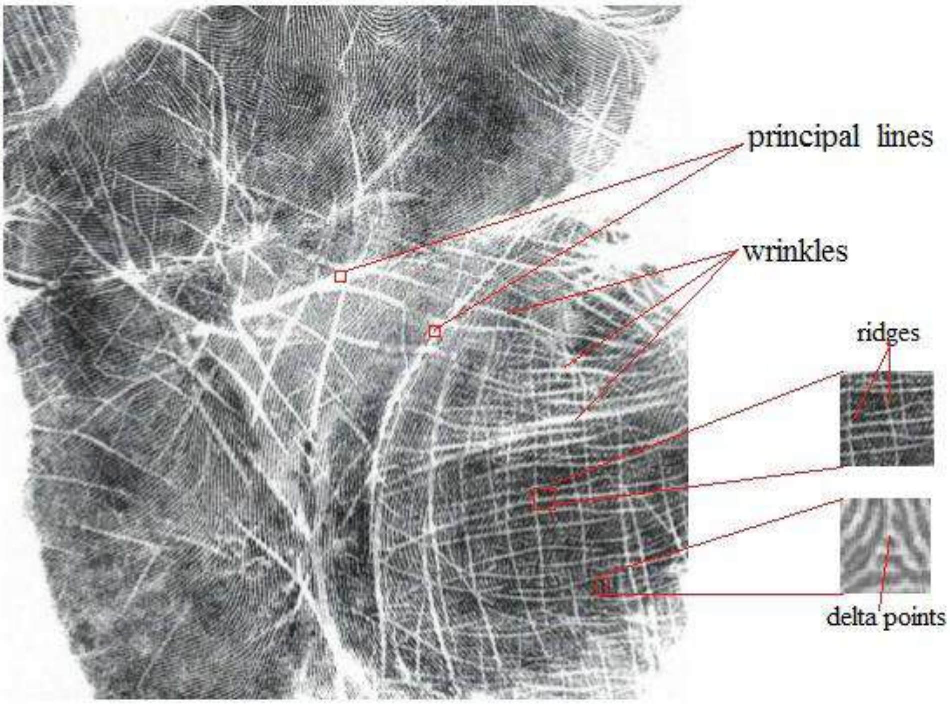


Figure III. 1: The three principal lines on a typical palm

III. 3 Proposed biometric system

We propose a multimodal biometric system (Multi Samples) based on palmprint which consists of two merged subsystems at the score level (see Figure III.2). Each subsystem represents a unimodal system consisting of four modules: biometric capture (palmprint image), feature extraction module comparison module and decision module.

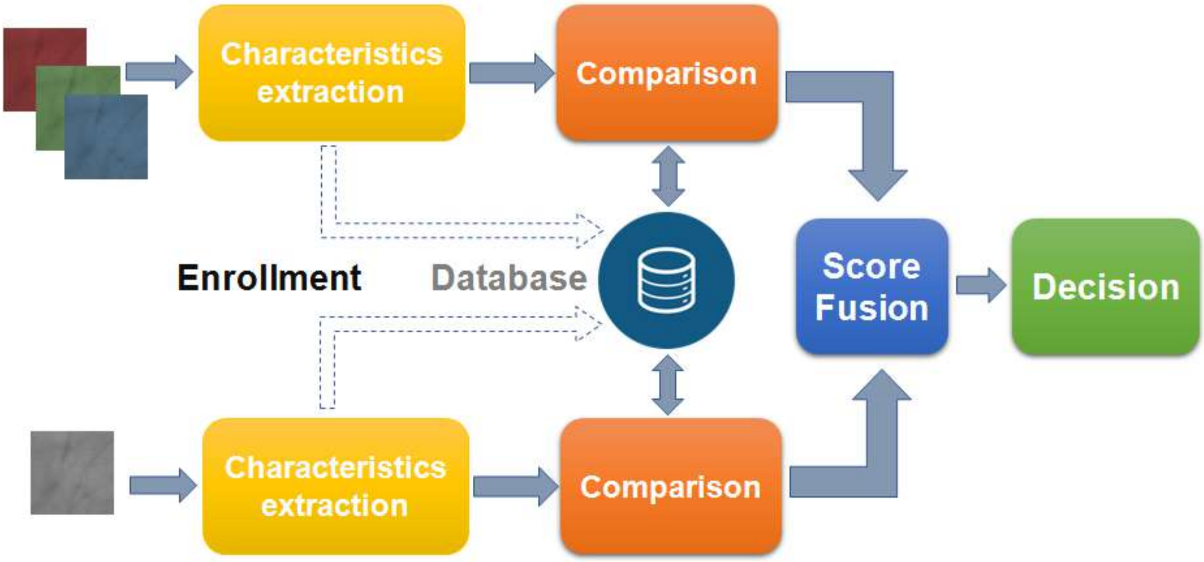


Figure III. 2: Multimodal system (with fusion at score level).

III.4 Palmprint image acquisition device

To achieve an online identification by palmprints in real time, one needs 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.

The picture 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, a light controller, and 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. The system that we have developed contains four basic stages of processing:

1) In the sensor stage, a biometric image is captured and enrolled as an input to the system which is used for verification or identification.
2) 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.
3) 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.
4) 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 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 (see figure **III.4**).

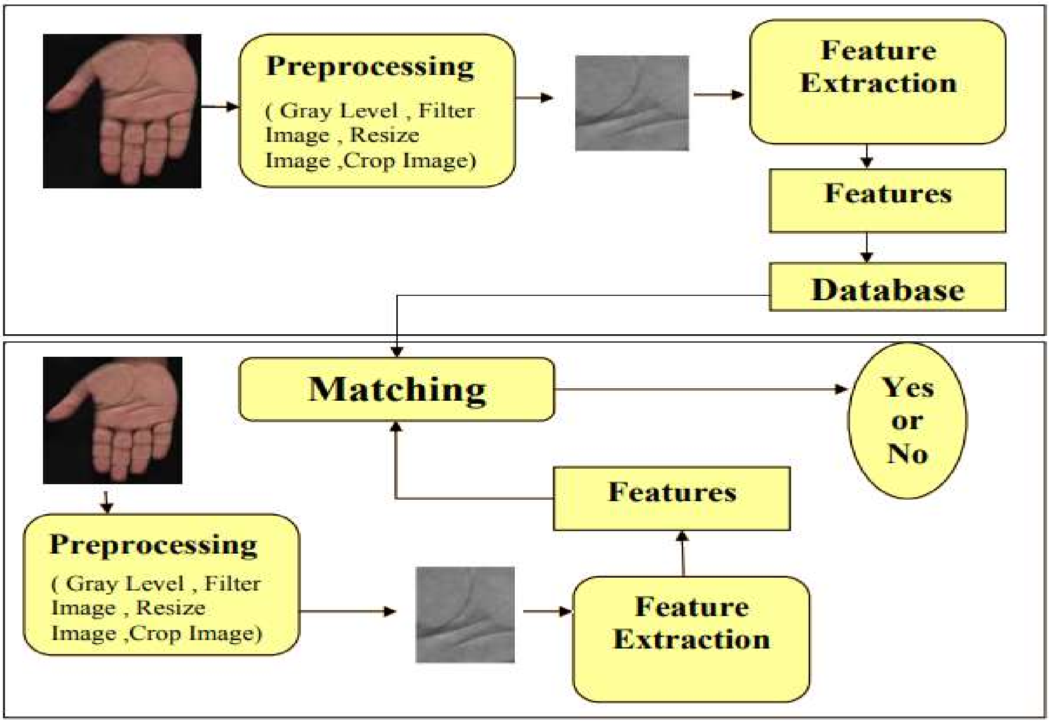


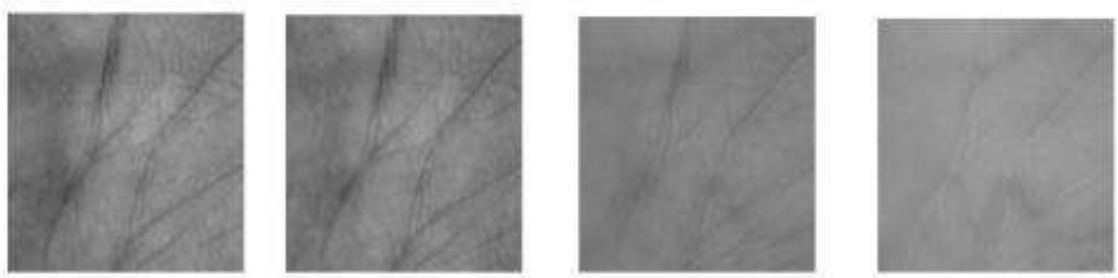
Figure III. 4: The Principe of palmprint recognition device

Compared to other physical characteristics, palmprint identification has various advantages:

- Collect all features of a palmprint, give us a robust biometric system.
- Little risk of intrusion.
- High rate of user acceptance
- Low resolution image processing.

III.4.1 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. 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 [30].



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

Figure III. 5: Examples of PolyU database bands: a) Blue, b) Green, c) Red, d) NIR.

III.4.2 Database separation

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, 5^{th} and 9^{th} are processed.

b) **Testing 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.5 Results and discussion

III. 5.1 Development 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) I3-4005U CPU @ 1.70 GHz.
- ❖ System Type : Operating System 64 bits .

2) Software environnements

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 choice of the best parameters has an impact on the recognition rate of the system. Therefore, we have chosen the best of them after the adaptation process, and apply them in the algorithm. The Two following tables presents the Threshold, EER, ROR and RPR, the first one for the different number of functions in the case of Niter=20 in palm print database(Blue band), and same thing for second one for the different values of number of iteration (Niter) in the case of number of functions =10. 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 (see Table **III.1**).

(Niter: number of algorithm iteration, Nf: Gaussian functions of each input variable).

Table III. 1: Results of different values of Nf in case of (Niter=20).

Data Base		Nf	Number of neurons	EER (%)	T_0	ROR (%)	RPR
100 Person	Blue	**5**	**25**	0.221	0.127	98.555	57
		10	**100**	0.111	0.168	99.666	78
		15	**225**	0.111	0.143	99.666	99
		20	**400**	0.111	0.125	99.666	98

The figure that we will show below represents a graph of the identification rate in terms of number of function (Nf).

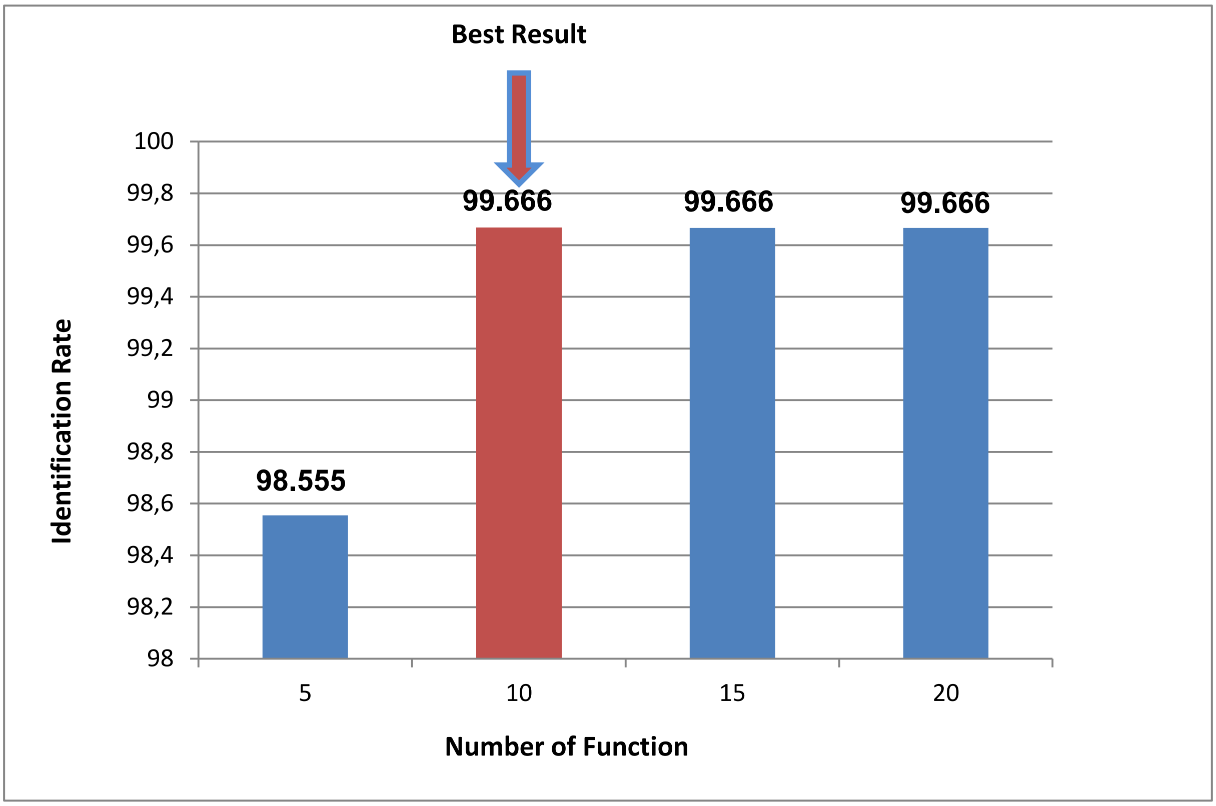


Figure III. 6 : Bar graph showing the identification rate in terms of Nf.

From the Table above **III.1** and **Figure (III.6)**, we can observe that the closed set identification accuracy becomes very high at certain classifiers for blue band, where it reaches 99.666% three times respectively in the cases of numbers of functions 10, 15 and 20.

From the **Table III.1,** we conclude that the best result gives by the number of functions Nf= 10 after comparing the results to each other and choosing the best among them which is Nf 10 and , It was choosen because it has the least time of execution comparing with the cases of number of functions 10,15 and 20 in addition if we continue to change the values of Nf we will cause the loss of best result and we will have returned to the worst results, after selecting the best result of Nf , we fixed this value and we began to change the values of iteration numbers, hopefully that we get better results.

Table III. 2: Results of ROR and RPR for different values of Niter in case (Nf =10).

Niter	Closed set identification		Closed set identification	
	EER (%)	T_0	ROR (%)	RPR
5	0.111	0.178	99.666	28
10	0.111	0.172	99.666	47
15	0.111	0.167	99.666	67
20	0.111	0.168	99.666	78
25	0.111	0.163	99.666	77
30	0.111	0.165	99.666	74
35	0.111	0.166	99.666	63
40	0.111	0.167	99.666	59
45	0.111	0.160	99.666	51
50	0.111	0.159	99.666	44

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

Depending on the table's results (Table III.2), which includes the results of ROR and RPR (Closed set identification mode).

We observe from table (III.2) that the values of Nf from 5 to 50, which give the results of ROR (99.666%) respectively, stable values of ROR. so depending on stability of result and choosing the smallest number of iteration numbers we conclude that the perfect result of Niter is 5 which contributes with the numbers of function to give as the best results of the lowest error value (iteration number =5 and number of functions = 10).

III.5.3 Unimodal system results

We will apply the best of iterations number (Niter) and function number (Nf) which were tested in the case of the blue and retest them in Nir, Green, Red images.

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

Table III. 3: Unimodal results.

Bands	Open set identification		Close set identification	
	EER(%)	T_0	ROR(%)	RPR
Red	0.666	0.130	97.44	46
Green	6.555	0.127	82.66	93
Blue	0.111	0.168	99.666	28
NIR	0.111	0.196	99.555	8

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

The following curves **(Figure III.7),** represent **FRR** versus **FAR** graph and **CMC** curve **(Figure III.8**).

This curve **(Figure III.7)** shows the equal error rate (EER) of each band as a function of the false rejection rate (FRR) and the false acceptance rate (FAR).

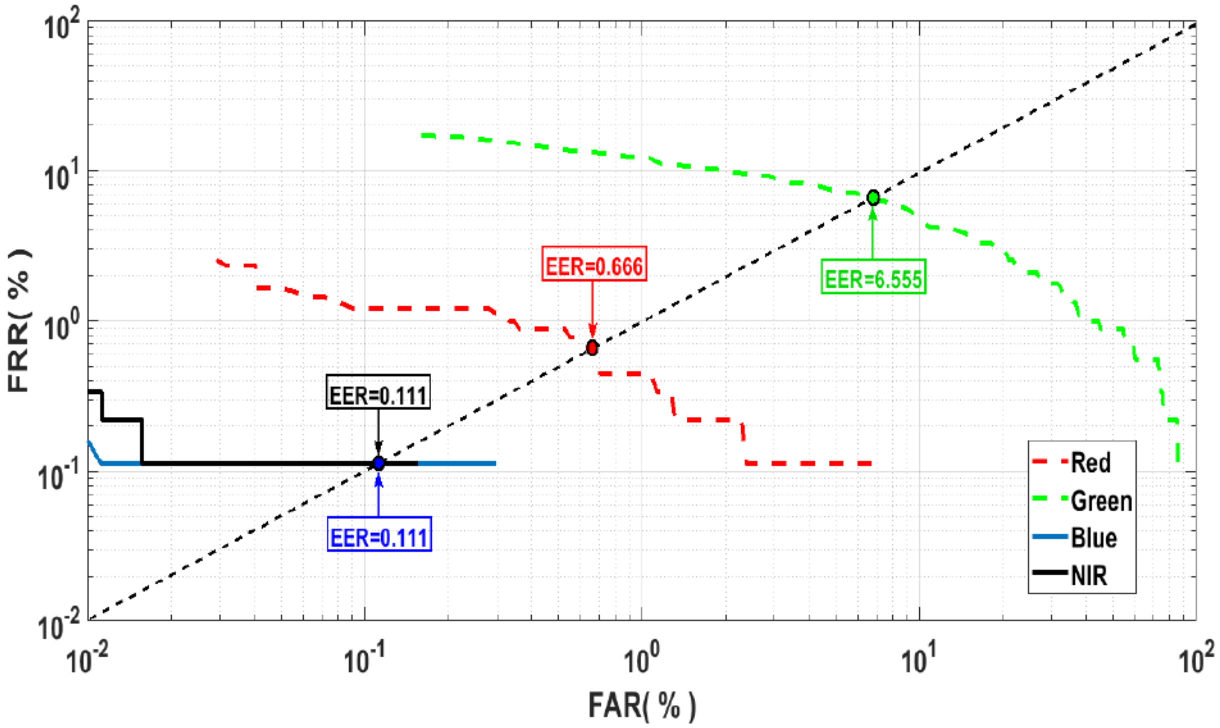


Figure III. 7: Unimodal ROC curves.

However, figure **III.8** illustrates the CMC curves of different bands.

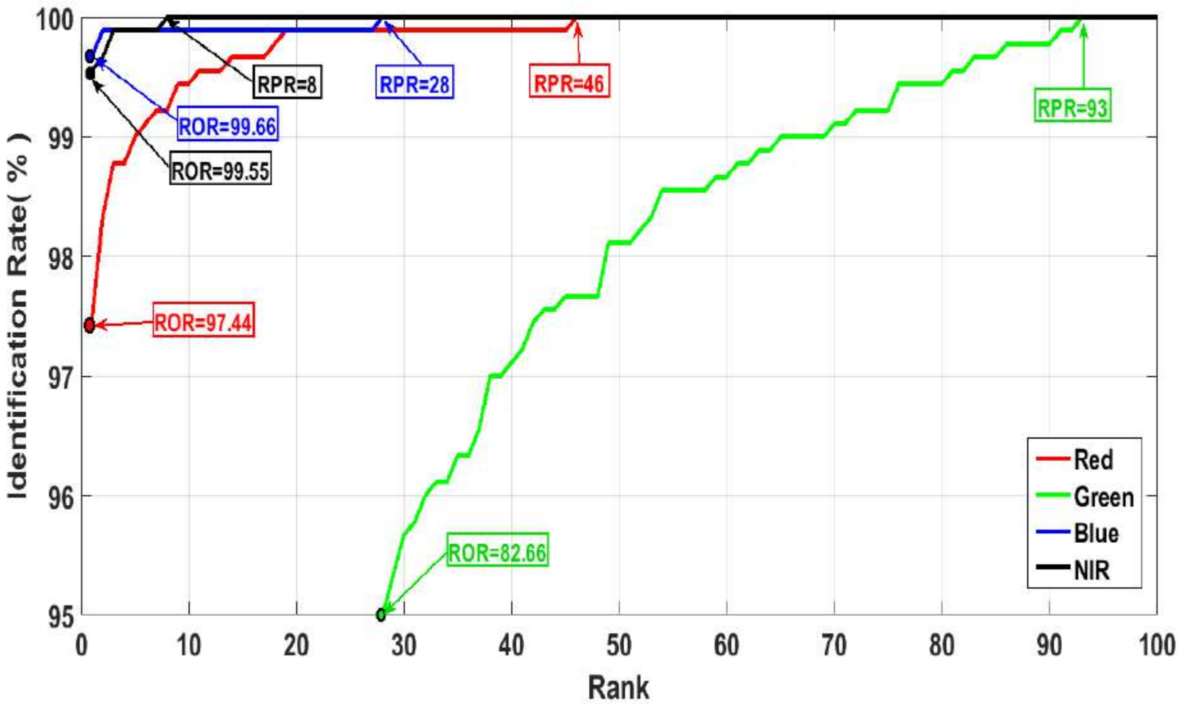


Figure III. 8: Unimodal CMC curves.

III.5.3.1 Discussion

From the **Table (III.3)** and **Figure(III.7)**, 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 99.666% with RPR=28.
- in the case of Green band at the given a upper limit EER equal 6.555 at T_0=0.127 , because the Green band as given not sufficient and poor information compared with another bands.
- Other bands produce acceptable values compared to the green, but the blue remains the best result even if the NIR has almost same result of EER but comparing their Rank-one recognition (ROR) the blue was the closest to the perfect result.

III.5.4 Multimodal system results

As we know the orientation to the multimodal biometric system is considered one of the best solutions to improve performance and researchers has proven that the use of multimodal biometrics will provide a more reliable and robust system. In this sense, during our experimental study based on a multi-sample system the information presented by different bands (Blue, Green, Red, and NIR) fused to make the system efficient.

Four possible levels of fusion can be used for integrating data from two or more modalities , 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.

The fusion at the matching-score level is preferred in the field of biometric recognition because there is sufficient information content and it is easy to access and combine the matching scores. In our system we adopted the combination approach, where the individual matching scores are combined to generate a single scalar score, which is then used to make the final decision. During the system design we experiment five different fusion schemes: Sum score, multiplication score, minimum score, maximum score and Sum weighting score. Suppose that the quantity S_i represents the score of the i^{th} matcher (i = 1; 2; 3; 4) for different palmprint color bands (BLUE, GREEN, RED, and NIR) and S_F represents the fusion score. Therefore, S_F is given by (See Table **III.4**):

Table III. 4: Score combination methods.

Method	**Formula**
Simple Sum	$S_F = \sum_{i=1}^{N} S_i$
Multiplication	$S_F = \prod_{i=1}^{N} S_i$
Minimum Score	S_F =Min(i=1 to N) S_i
Maximum score	S_F =Max(i=1 to N) S_i
Weighted Sum	$S_F = \sum_{i=1}^{N} W_i^* S_i$

With: $W_i^* = \frac{1 / \sum_{j=1}^{N} \left(1 / EER_j \right)}{EER_i}$

Where W_i^* denotes the weight associated with the matcher i, with Σ W_i^*= 1, and *EERi* is the equal error rate of matcher i, respectively.

In our case we have performed two types tests of the merger, the first one was fusing the three bands Blue, Red, and Green. Then in the same way we have merged those three colors besides the NIR band, with the registration of the EER values, the threshold, the ROR and the RPR for both tests and their results are represented in the table **III.5**:

Table III. 5 Multimodal results.

Fusion	R+G+B				R+G+B+NIR			
	Open Set		Closed Set		Open Set		Closed Set	
Rules	T0	EER	ROR	RPR	T0	EER	ROR	RPR
Sum	0.131	0.111	99	2	0.181	0.111	100	1
Mul	/	/	80	2	/	/	80	2
Min	/	/	80	2	/	/	80	2
Max	0.193	0.222	99	4	0.247	0.114	100	1
W Sum	0.185	0.035	100	1	0.060	0.015	100	1

In this case, the two following **figures III.9** and **III.10** show multimodal **ROC** and **CMC** curves**.**

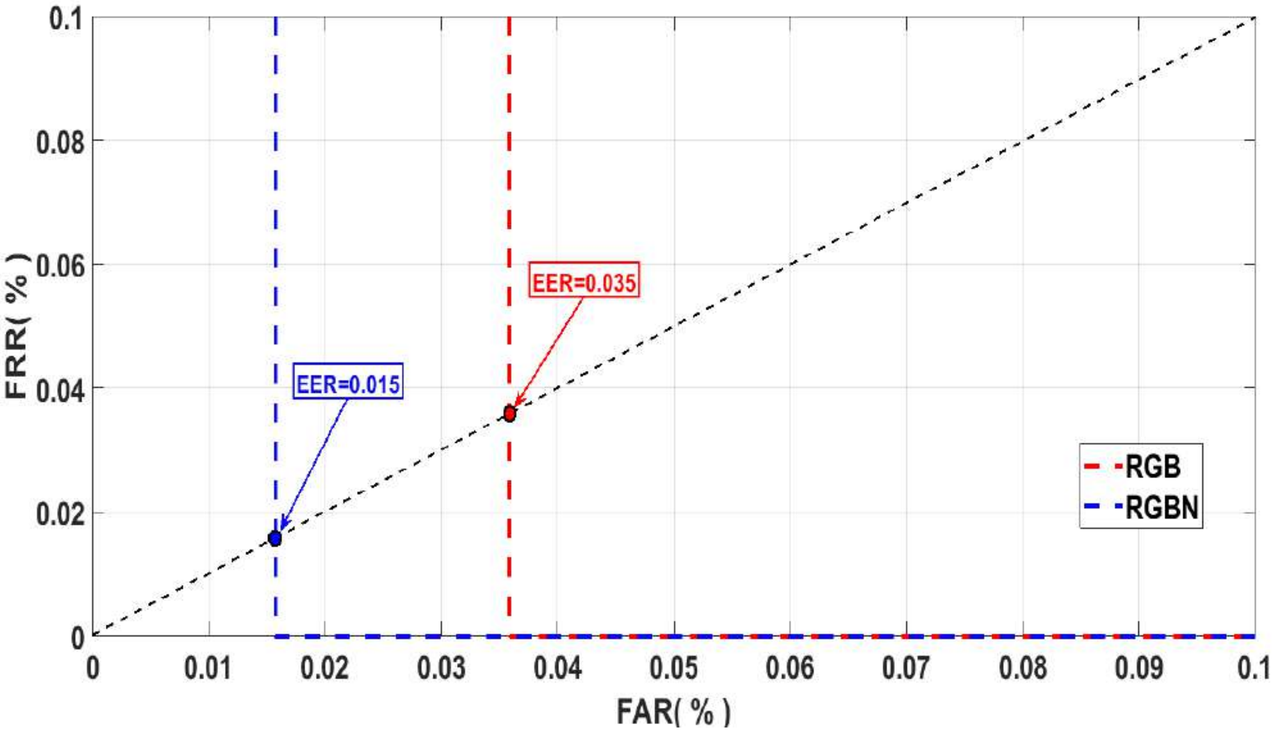


Figure III. 9: Multimodal ROC curves.

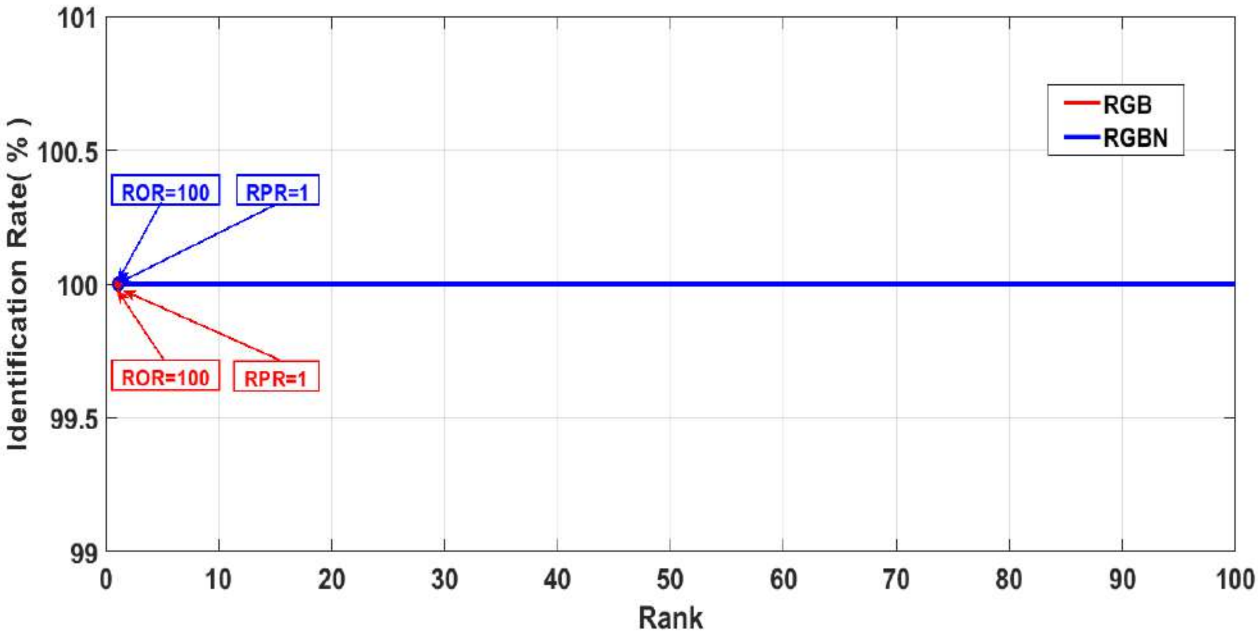


Figure III. 10: Multimodal CMC curves.

III.5.4.1 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.4)**, we can observe the advantages of using the R, G, B, N fusion:

- The fusion of bands Red, Green, Blue and NIR in the weight sum has the minimum EER equal to 0.015 And a threshold equal to T_0= 0.060 and that was the best result, that's for the Open set identification and the closed set identification we notice that the Rank-one recognition (ROR) has a value of 100% and takes only one step to reach it on the Receiver Operating Characteristics (ROC).
- From the results obtained we can said that the precision of the multimodal system is better than that of the unimodal system.

III.6 Conclusion

We can deduce that the feature extraction step is a very necessary step for every biometric system and 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 human physiological characteristics for identifying an individual is now a widespread method of the identification and the authentication. The biometric identification is a technology which uses several image processing techniques, The Palmprint recognition has been verified investigated over 10 years. During this period, many different problems related to the palmprint recognition have been addressed.

Artificial neural networks have been shown to be a useful tool for prediction, function approximation and classification. The real benefits of a modeling technique that can accurately reproduce any measurable relationship are enormous. The benefits of neural networks are particularly apparent in applications where a full theoretical model cannot be constructed, and especially when dealing with non-linear systems.

The work presented in this dissertation is part of the context of the automatic identification of people based on their biometric descriptors, and it was focused on the optimization of neural networks Unfortunately, he had a major problem represented in his 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 the artificial neural network system as modeling tool of biometric modality.

We had formulated the identification of biometric images as a quadratic problem optimization. The Conjugate Gradient method algorithm was presented as simple algorithm to find the best solution that minimizes the error approximation of the biometric image.

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

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

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Abstract

The purpose of this work is to develop biometric system to recognize persons based on their palmprint. Here, we propose to use the polyU database. Initially we discussed the concept of the biometric system and its basic components. Mainly, this work aims to propose an extraction algorithm to find an efficient characteristic vector to be used as palmprint template. The extraction of characteristics depends on the modeling of the biometric image by an artificial neural network that belongs to the family of universal function approximator tools. Unknown parameters are defined through quadratic error function optimization with gradient method. Finally, the efficiency and performance of the proposed biometric system is illustrated through some experiments implemented using Matlab software.

Keywords: biometric system, artificial neural network, Multimodal biometric systems, Palmprint recognition, Universal approximation, Gradient method.

ملخص

الغرض من هذا العمل هو تطوير نظام بيومتري للتعرف على الأشخاص على أساس راحة اليد. هنا ، نقترح استخدام قاعدة البيانات polyU. في البداية ناقشنا مفهوم النظام الحيوي ومكوناته الأساسية. يهدف هذا العمل أساسًا إلى اقتراح خوارزمية استخلاص للعثور على شعاع مميز فعال ليتم استخدامه كقالب لراحة اليد. يعتمد استخراج الخصائص على نمذجة الصورة البيومترية بواسطة شبكة عصبية اصطناعية تنتمي إلى مجموعة أدوات التقريب الوظيفية الشاملة. يتم تعريف المعالم غير المعروفة من خلال تحسين وظيفة الخطأ من الدرجة الثانية مع طريقة التدرج. أخيرًا، يتم توضيح كفاءة وأداء النظام الحيوي المقترح من خلال بعض التجارب المنفذة باستخدام برنامج Matlab.

الكلمات المفتاحية : النظام البيومتري, شبكة العصبونات الاصطناعية, نظام بيومتري متعدد الوسائط , التعرف براحة اليد , التقارب العالمي , طريقة التدرج.

Résumé

L’objectif de ce travail est de développer un système biométrique pour la reconnaissance des personnes en se basant sur l’empreinte palmaire. Ici, nous proposons l’utilisation de la base de données polyU. Au début, nous discutons le concept du système biométrique et ses principales composantes. Ce travail vise principalement à proposer un algorithme d’extraction pour déterminer un vecteur caractéristique en se basant sur la modélisation de l’image biométrique à l’aide d’un réseau de neurone artificiel. Ces derniers font parties des outils d’approximation des fonctions. Des paramètres inconnus sont déterminés à travers l’optimisation de la fonction d’erreur quadratique par la méthode du gradient. A la fin, l’efficacité et les performances du système biométrique proposé sont illustrées à travers un ensemble d’expérimentation implémenté en Matlab.

Mots-clés: système biométrique, réseau de neurones artificiels, systèmes biométriques multimodaux, reconnaissance Palmprint, approximation universelle, méthode du gradient.