KASDI MERBAH UNIVERSITY - OUARGLA

Faculty of New Information Technologies and Communication

Department of Electronics and Telecommunications

ACADEMIC MASTER'S DISSERTATION

Field: Automation

Specialty: Automation and system

Presented by:

MOUADENE Mouna　　　　ARBAOUI Brahim

Theme:

Newborn identification and recognition system through footprint

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Publically presented in 22/06/2023

Before the jury:

Dr. BENARABI Bilal	**MCA**	**President**	**UKM Ouargla**
Dr. SAMAI Djamel	**MCA**	**Examiner**	**UKM Ouargla**
Dr. ROUABAH Boubakeur	**MCB**	**Supervisor**	**UKM Ouargla**
Dr. KAFI Mohamed Redouane	**MCA**	**Co-Supervisor**	**UKM Ouargla**

Dedication

ARBAOUI Brahim

I dedicate this work to my precious family, my father who shaped me into the person i am today and supported me in my desperate days, to my mother who sank me in her sea of kindness and prayers, to my big brother Omar who's been my support all my life to my big sisters Hadjer, Iman and Chaima who taught me everything they know, to my little sisters Zaineb, Romaissa and Soundes who always believed in me and of course my friends Issam, Wail and Aissa and others that cheered for my success and seeked my well being

Lastly, my partner Mouna and my supervisor Dr. Rouabah who contributed in this work and make it possible.

Dedication

MOUADENE Mouna

I dedicate this work to my dear family, to my beloved parents who contributed to building my personality and pushed me towards achieving excellence. Thanks to my father who believed in my abilities and encouraged me to reach what I am now. For my mother, I thank you for your priceless love and giving.

I extend my sincere thanks to my dear grandmother, my first mother. Thank you for your sincere prayers. May God prolong your life and make you a pillar of our home and a heart that embraces us all.

To my dear brothers Amani, Djoumana, Mohamed Abd allah and my younger brother Ahmed Abd Rrahman, you are my happiness and the secret of my laughter. You are my strength and support after my father. Thank you for the enjoyable times and continuous support.

I cannot forget my colleague Brahim, with whom I started this journey. Thank you for your continuous cooperation and encouragement. I also thank my teachers, led by Dr. Rouabah Boubakeur, who believed in our success and helped us achieve the best.

Table of contents

List of Figures

List of Tables

الملخص :

نظام التعريف والتعرف على حديثي الولادة عن طريق بصمة القدم هو نظام مبتكر يهدف إلى تحسين وتسهيل عملية تحديد هوية الأطفال الرضع في المستشفيات والمرافق الصحية عن طريق بصمة القدم .
النظام يساهم في رقمنة القطاع الصحي وتحسين إدارة الملفات الطبية بشكل عام. يعزز الرعاية الصحية والأمان من خلال ضمان دقة التعرف والمصادقة على هوية الأطفال الرضع. يعتمد النظام على استخدام تقنية بصمة القدم للمولود وبصمة الأصبع للأم. وكما يعمل النظام على زيادة الأمان والخصوصية بفضل التحقق الدقيق من الهوية، وتوفير سجل طبي دقيق ومحدث للمولود يمتد طوال حياته. كما يساعد النظام في القضاء على أي ارتباك أو أخطاء محتملة للمعلومات في المستشفيات، وكذا منع الاختلاط بين الأطفال حديثي الولادة, إضافة إلى تحسين جودة الرعاية الصحية للمولود والأم.
تعكس هذه الابتكارات الجذرية في نظام التعريف والتعرف على حديثي الولادة التطور التكنولوجي في مجال الرعاية الصحية وتعزز التحول الرقمي في قطاع الصحة. يعد هذا النظام إضافة قيمة حقيقية للمرافق الصحية والأسر، ويسهم في تحسين جودة الرعاية والسلامة للأطفال الرضع وتحقيق تجربة صحية متميزة للأمهات والأطفال.

الكلمات المفتاحية : رقمنة القطاع الصحي/ التعريف / التعرف / حديث الولادة / بصمة القدم / بصمة الإصبع/ ملف طبي رقمي /الرعاية الصحية / الأمان والخصوصية /المصادقة / الاختلاط .

Abstract :

The Identification and Recognition System for Newborns through Footprint is an innovative system aimed at improving and facilitating the process of identifying infants in hospitals and healthcare facilities using their footprints. The system contributes to the digitization of the healthcare sector and enhances the management of medical records. It enhances healthcare and safety by ensuring accurate identification and authentication of newborns. The system relies on the use of infant footprints and maternal fingerprints. It increases security and privacy through precise identity verification and provides a precise and updated medical record for the newborn throughout their life. The system helps eliminate any confusion or potential errors in information within hospitals and prevents mix-ups among newborns. Additionally, it improves the quality of healthcare for both the newborn and the mother, reflecting the technological advancements in healthcare and promoting the digital transformation in the health sector. This system adds real value to healthcare facilities and families, contributing to the improvement of care and safety for newborns and achieving an exceptional healthcare experience for mothers and children.

Keywords: Healthcare / digitization / Identification / Recognition / Newborns / Footprint / Fingerprint / Digital medical record / Healthcare / Safety / Authentication / Mix-up.

Résumé :

Le système d'identification et de reconnaissance des nouveau-nés par empreinte de pied est un système novateur visant à améliorer et faciliter le processus d'identification des nourrissons dans les hôpitaux et les établissements de santé grâce à l'empreinte de pied. Le système contribue à la numérisation du secteur de la santé et à l'amélioration de la gestion des dossiers médicaux de manière générale. Il renforce les soins de santé et la sécurité en garantissant une identification précise et une authentification de l'identité des nourrissons. Le système repose sur l'utilisation de la technologie d'empreinte de pied pour les nourrissons et d'empreinte digitale pour la mère. De plus, le système améliore la sécurité et la confidentialité grâce à une vérification précise de l'identité et fournit un dossier médical précis et à jour pour le nourrisson tout au long de sa vie. Il aide également à éliminer toute confusion ou erreur potentielle d'informations dans les hôpitaux et prévient les échanges de nourrissons. En améliorant la qualité des soins de santé pour le nourrisson et la mère, ces innovations radicales dans le système d'identification et de reconnaissance des nouveau-nés reflètent les avancées technologiques dans le domaine des soins de santé et favorisent la transformation numérique dans le secteur de la santé. Ce système ajoute une réelle valeur aux établissements de santé et aux familles, contribuant à l'amélioration des soins et de la sécurité des nourrissons et offrant une expérience de santé exceptionnelle pour les mères et les enfants.

Mots-clés : Numérisation du secteur de la santé /Identification / Reconnaissance / Nouveau-nés / Empreinte de pied / Empreinte digitale / Dossier médical numérique /Soins de santé / Sécurité / Authentification / Échanges.

Chapter 01:
Introduction

Chapter 01: ***Introduction***

Biometrics refers to the use of unique physical or behavioral characteristics to identify and authenticate individuals. It has had a significant impact on the social aspect by providing individuals with a unique, verifiable identity. This has contributed to enhancing security and simplifying operations. However, the application of biometrics in the health sector Raises concerns related to privacy and data protection To ensure the ethical use of biometric information, it is important to ensure the implementation of strong security measures, transparent policies, and strict regulatory rules to protect the privacy of individuals. The application of this to this sector is represented in the digitization of the health sector, as it is considered one of the modern and important trends in the field of technology and business in the current era (in our country). Where it is witnessing a digital transformation and technological revolution, as it plays an important and decisive role in improving the quality of health care and facilitating access to health services.

1.1 Motivation:

The health sector should be witnessing a remarkable shift towards digitization and the adoption of modern technology to improve health services and facilitate access to them. The digital system in the health sector is an important step towards achieving efficiency and continuous improvement in healthcare. However, at the same time, this transition faces some problems that affect the effectiveness of management and make it not fully integrated.

Without the use of digitization in the health sector, many problems and challenges that affect the efficiency and quality of health care arise.
As for patients' medical files or the collection and analysis of statistical data, in the absence of a unified system for recording data, this results in a variety of methods of documentation and registration between different health institutions. This hinders comprehensive analysis and accurate comparison between different institutions and regions. This is to:

1. Difficulty accessing and changing information:
In the traditional system, it is difficult to access health information about patients. This requires searching through paper records stored in different places, and finding the required information can be a difficult and costly task in terms of time and effort.
So stored paper records must be appropriately organized and categorized to facilitate finding the required information. However, there is a poor system for their organization and sometimes, health records are distributed across different health institutions and clinics. The patient may have records in hospitals, general practitioners' offices, specialty centers, laboratories, and pharmacies. This means that the search for integrated and comprehensive

information may be challenging, and in it the possibility of error in finding this information increases. The individual needs to coordinate with each institution to obtain the complete information. This is what makes the time spent searching in the traditional system, requiring a lot of time and effort. The individual must go to the various health institutions, fill out forms, submit requests, and wait to receive the required information. This can take a long time and this negatively affects quick health decision-making and the provision of necessary care. In the event of a change in patient health information, it may be difficult to update paper records effectively. This may require deletion or addition of new information and modification of old records, which increases the possibility of errors or incomplete information.
The delay in the availability of information in the paper system required the exchange of medical information to send paper files, formatting and manually arranging files and documents. This process can be complex and time consuming, especially when dealing with large files or a large number of patients with traditional delivery methods. This process can be time consuming and may cause delays in the availability of important medical information. This delay can negatively affect doctors' ability to make quick decisions and provide needed care in a timely manner.

2. Loss or damage to paper files: Paper files are subject to loss or damage due to accidents or natural disasters, as hospitals and health centers are exposed to accidents or natural disasters such as fires, floods or earthquakes. In such cases, paper files may be subject to serious damage or complete loss, which leads to the loss of important health information for patients or human errors. A human error may occur in organizing and storing paper files, causing them to be lost or damaged. Files may be placed in inappropriate places or handled incorrectly, exposing them to loss or damage.

This puts patient records at risk and causes the loss of important information and the complete health history of patients. It also requires a lot of space for storage and preservation, and it may be stored in inappropriate conditions. Humid conditions, dust, or other environmental factors expose paper files to wear and tear over time. These problems make paper files unreliable and pose a threat to the integrity and security of health information.

3. Possibility of human error: In a traditional system, which requires manual recording of health information, numbers or letters can be misspelled, resulting in incorrect data being recorded. This may cause information confusion and disturb its accuracy and correctness, as there may be errors in recording patients' personal data such as name, date of birth, or health insurance number. These errors can lead to switching of information between patients or to the merger of health files of different patients. In the case of updates or amendments to health information, it is difficult to make changes to paper files effectively. This may require noting modifications or adding additional paper, which increases the possibility of error or confusion in the information.

4. Lack of security and privacy: the paper file is easily exposed to theft or unauthorized access by unauthorized persons, and this may expose patient data and sensitive personal information to danger, and it may be used in illegal ways or for illegitimate purposes, and it is also difficult to determine and monitor access to Medical files and prevent unauthorized persons from accessing them. It can be difficult to keep track of records and to know who accessed the information and when.

With the use of digitisation in the health sector, these problems can be overcome and significant improvements in efficiency, quality and safety can be achieved. The digital system enables health information to be stored and managed electronically, which facilitates quick and secure access and exchange between stakeholders. Strong security measures can also be implemented to protect personal data and maintain patient privacy.

5. Newborn confusion or loss: Newborns may be confused if there is no effective system to record their identification. Traditional bracelets are used to identify children. These bracelets usually include basic and limited information such as the mother's name, date of birth, and gender, but they face many problems and challenges. An error in identification may occur in the event of exchanging bracelets between children, whether by mistake, due to birth at the same moment, lack of distinction between them, or a mistake. Simple while writing information on the wristbands, such as a misspelling of a name or gender identification, this may lead to confusion in identifying the child and staff need to perform additional procedures to verify his identity, such as comparison with manual records or calling witnesses to confirm the correct identity. This can take a long time and cause delays in redirecting the child to his or her real parents. It affects the functioning of the hospital. The child may also be at risk of losing the bracelets during transfers between departments or while being cared for with the limited information they contain, which impedes the provision of more detailed medical or administrative information. Traditional bracelets are usually made of materials such as plastic, which cause some discomfort and irritation to the child's skin if worn for a long time. Given these problems, there is a need to search for more advanced and digital solutions for child identification in hospitals, which contribute to providing more accurate and effective health information documentation and improving child care.

1.2 Related works:

In the absence of digitization, Algerian hospitals adopt traditional methods of information exchange, such as telephone calls to exchange information, which often leads to unclear information and confusion in communication. Staff may need to make several calls to obtain the required information, causing delays in achieving a prompt and effective response. Or a fax that is most of the time slow and error prone. The necessary documents have to be prepared and sent by fax, which takes time and effort. Recipients may need to manually re-enter information into their systems, which increases the potential for errors. Or even relying on postage paper that required a long time to deliver and receive. Documents must be printed, filled out, and sent by post. Delivery delays may occur due to the sorting and delivery process. This means that medical information is not immediately available and difficult to access when needed. This can cause delays in the availability and exchange of medical information between hospitals, clinics, laboratories and pharmacies.

The use of a wristband system to protect children from confusion and loss is a common solution in Algerian hospitals. This system can be effective within the hospital where the process of distributing and applying bracelets to newborns can be controlled.
As the bracelets match the identity of the infant, they can provide a convenient system for identifying the child and documenting basic information, such as the mother's name, date of birth and gender. The bracelets attach to an infant's hands or feet, and come with identifying information unique to each child.
However, it should be noted that this system is not feasible outside the hospital, as the child may lose the bracelets during transport. If a child loses or damages the wristbands, it is difficult to identify him/her. In addition, it may be difficult to provide compatibility between hospitals as the wristband systems used differ in terms of design and materials used. This makes it difficult to achieve full compatibility between these systems, with respect to the wristband systems used, which increases the possibility of mixing if children are transferred between hospitals.

1.3 Contribution :

The system of identification and recognition of newborns by footprint is an incentive for Algerian hospitals to achieve digitization in the health sector and improve the quality of healthcare and patient safety. It is an important step towards modernizing health operations and enhancing efficiency and accuracy in recording and managing patient information. This system provides an effective and reliable way to identify newborn babies and create a permanent private digital medical file that is available and updated at every visit to the doctor or hospital. The complete file of the child is displayed at each visit, and thus the treating medical team has a comprehensive view of the child's health history, previous diagnoses, treatments received, and vaccinations given. This system facilitates the follow-up and provision of health care to the child, as the necessary information is provided to doctors and nurses quickly and easily, which leads to improving the quality of care and avoiding medical errors. In addition, the child's digital medical file remains with them throughout their growth and development, including in the event of their death. This helps in providing integrated and continuous medical records for the child over the years.
Digitization relies on storing digital medical files in secure, centralized databases. This storage takes place in protected and advanced servers that ensure the protection and confidentiality of medical data. By storing digital medical files in central databases, several benefits are achieved. One of them is space saving, as maintaining hard copies does not require a lot of storage space. The challenges of storing and maintaining traditional paper files, such as wear, tear and loss, are also avoided.
The security and privacy of information is one of the main priorities in this system, as several measures are taken to ensure the confidentiality and protection of the personal and medical information of the mother and child, as users' access to digital medical files is organized based on the principle of need to know. Only authorized persons have access to information

necessary to perform their medical duties. Medical information can be easily updated as soon as there are updates or changes in the child's condition. All new visits, treatments and diagnoses are recorded in the digital medical file. By recording each birth, the information in digital systems can be used to create more accurate and comprehensive statistics. These statistics can be used in evaluating health performance, analyzing health data, and making necessary policy decisions.
The use of the system for identifying newborns by footprint contributes to avoiding problems of confusion and loss, as unique data for each newborn child has been registered in the system with a footprint. This ensures accurate identification of each child and prevents unintentional exchange or mixing. Children's information is recorded and stored electronically in the system, thus avoiding problems of damage or loss of traditional paper bracelets. This information can be accessed easily and quickly when needed. The private system works to achieve compatibility between different hospitals and health facilities through the use of a common system for registration and sharing of children's information. This reduces the possibility of mixing when transferring children between institutions, and this reduces the risk of mixing and getting lost, and contributes to improving the safety and quality of health care for children.

1.4 Following work :

In the following pages, we will discuss and explore through this note in general on recognition systems and we will focus on the importance and benefits of using footprint recognition systems in identifying newborns. We will explore how to provide an effective and reliable means of verifying the identity of newborn babies and linking it to the information of the mothers. We will also discuss the digitization of the health sector and the role of footprint recognition systems in enhancing this process. We review how digital transformation can be achieved in the health sector through biometric applications. And we will highlight the importance of linking the mother to her newborn using the footprint and how to implement this by following accurate algorithms. We will talk about the processes used to ensure a correct matching between the identities of the mother and her newborn, and confirm their linkage in health records. The points we discuss in each chapter are:

- ***Chapter Two:***
  We will delve deeper into the understanding of biometrics in general and provide comprehensive information about the measurement methods used and the different recognition systems that can be applied. We will evaluate footprint recognition systems and discuss their accuracy and effectiveness in the context of their application.
- ***Chapter Three:***
  We will review the process of identifying newborns using footprints in detail. We will go through the steps of collecting footprint data and converting it into digital data for identification. We will provide a comprehensive look at the algorithms used to process footprint data and convert them into cognitive models that can be used in the recognition process. We will discuss the different types of algorithms and the

advantages and disadvantages of each type. We will talk about evaluating the accuracy and performance of algorithms and how to choose the most appropriate algorithm to achieve the best results in newborn identification.

- ***Chapter Four***:
  In this chapter, we will present the results obtained from the application of the footprint recognition system in the identification of newborns. We will analyze and discuss these results in detail. In addition to the system's ability to achieve accuracy and reliability in identifying newborns, we will also review the challenges that these systems may face and how to deal with them. We will also discuss the impact of this technology on the digitization of the health sector and the benefits it can provide in facilitating health procedures and improving the experience of patients and health care in general.
- ***Chapter Five:***
  In this chapter, We examined the broad results and identified potential future work for our research . The overall conclusion emphasizes the importance of our suggested approach in tackling significant difficulties in the healthcare sector, such as hospital baby mix-ups and digitization. We may generate a lifelong digital medical file by capturing the mother's fingerprint and the baby's footprint, improving record-keeping accuracy and safeguarding patient safety.

Chapter 02:
Biometrics

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2.1 Definition :

In a digital setting, a person's identification can be verified in one of three ways: using "something you learn" (such as a password or PIN number), "something you possess" (such as an ID card or a set of keys), or "something you are" (such as your fingerprints, face, or iris). The use of passwords and ID cards as surrogate representations for security and recognition has been shown to have a fundamental problem. However, passwords are readily forgotten or guessed, ID cards are simple to lose or misplace, and they can all be easily faked [1]. Therefore, the use of biometric identification is necessary.

Figure 2.1, shows the types of identification.

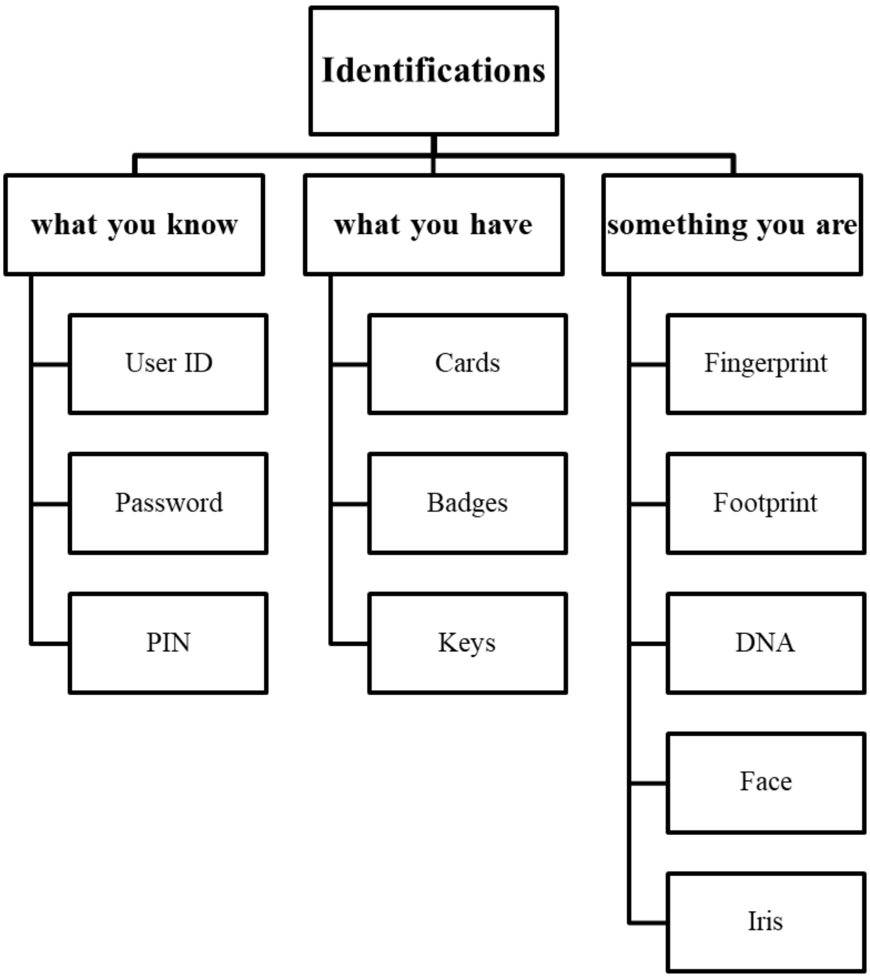

Figure 2.1 : Types of identification

Biometric identifiers are unique, measurable features that are used to label and describe persons. Biometric IDs are frequently divided into physiological and behavioral properties. Hand, Face, Ear, Eye, Finger Print, DNA, and other physiological biometrics would be used to identify people. Behavioral biometrics is concerned with a person's behavior, which refers to typing rhythm (Keystroke), signature, and voice. To describe the second kind of biometrics, some researchers have created the term behavioral biometrics.[2].

We could also define Biometrics as the science of determining an individual's identity based on physical, chemical, or behavioral characteristics. In simple terms, biometrics is concerned with the identification or authentication of persons based on physiological or behavioral features. During the last decade of the nineteenth century, biometrics were largely used in law enforcement to identify offenders. Since then, biometrics has been increasingly embraced in a variety of civilian applications to achieve individual recognition. compared to traditional authentication methods, biometric technology has shown to improve the reliability of safeguarding sensitive data. The primary benefit of biometric technology is security and convenience [3].

In contrast to passwords, biometric identification of an individual is generally permanent and cannot be freely modified. Because people generally keep their physiological or behavioral features on their person, this sort of authentication cannot be lost, forgotten, or easily shared with others, as other objects used for traditional authentication would. There are no human resources labor charges connected with password resets due to lockouts or expiration when using biometric authentication, which reduces a substantial percentage of system management costs.

Biometric systems typically undergo two key stages to determine an individual's identity based on their unique biometric or physical traits :

- **Enrollment phase:**

During the enrollment process, the person's biometric information is taken and saved in a database along with their identity. To extract significant and distinctive traits, the biometric data may (Figure), however, undergo additional processing at this stage.

- **Recognition phase:**

In order to identify the user during the recognition phase, biometric data is once again collected from the user and matched against database-stored templates.

2.2 History of biometrics:

Identifying individuals has been a desire for human beings since ancient times. All the known ancient civilisations (Babylions, chinese empire …) had ideas for identifying. They even tried using biometrics like hands or even finger prints. In the following we will see the origin of biometrics.

Biometrics has been through various stages of development over the years, we chose to present the most important events :

- Fingerprints have been used since 500 BC, as business transactions in Babylon documented on clay tablets contain fingerprints. Fingerprints were also used in commercial contracts by ancient Chinese merchants. Chinese parents used hand and foot prints to distinguish their children from one another. The ancient Egyptians moved on to employ face descriptors to identify merchants, distinguishing trustworthy merchants from new merchants based on previous business transactions.[4]

- **In 1858 :** Sir William Herschel, while working for the Civil Service of India, registered a handprint on the back of each worker's contract to identify workers who claimed a false day of wages from others. This was the first systematic recording of hand photographs and fingerprints for use in identity authentication.[4]
- **In 1870 :** Alphone Bertillon invented a method known as "anthropometric",for identifying persons based on documented information of their body measurements, physical descriptions, and pictures.[4] Figure 2.2

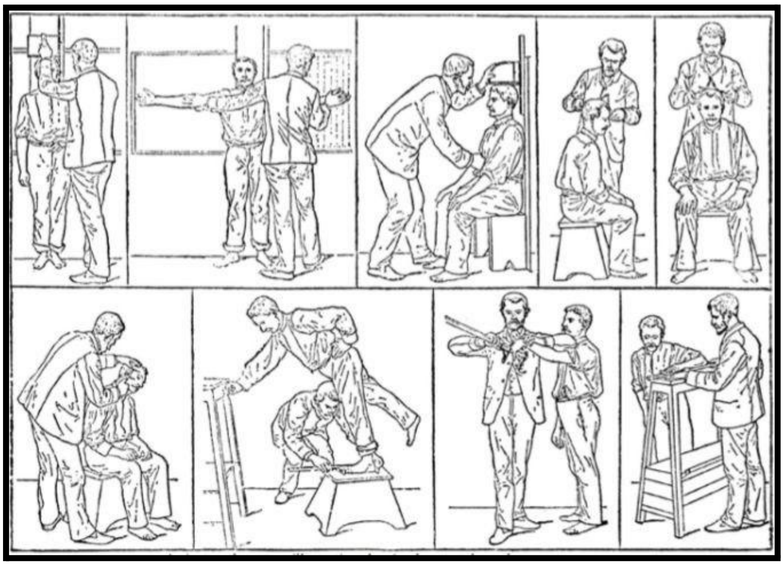

Figure 2.2 : Chart demonstrating "Bertillonage" measurements

- **in 1892 :** Sir Francis Galton published a detailed study on fingerprints , and he proposed a new categorization using all 10 fingerprints, and the details (minutiae) he utilised are still in use today.[4]
- **In 1936:** ophthalmologist Frank Burch presented the concept of using the shape of the iris as a technique of identifying people.[4]
- **In the 1960s:** Woodrow W. Bledsoe built the first semi-automated facial recognition system under contract with the US government.[4]
- **In 1960:** Gunnar Fant, a Swedish scientist, published the first model outlining the physiological factors of sound creation . His findings were based on an examination of X-rays of patients who made specific noises. These discoveries were used to better understand the dynamic components of sound and to create a speech recognition system.[4]
- **In 1963**: Hughes Research Laboratories published a study on aphids known as fingerprints.[4]
- **In 1970:**Joseph Perkell developed the original model for sound production, which was presented in1960, using x-rays to secure the jaw and tongue. The model has provided more understanding of the complex behavioural and biological components of sound.[4]

- **In 1977:** Veripen invented a device that allowed the dynamic characteristics of a person's signature to be digitally recorded. The development of this technology led to the testing of an automated handwriting checking.[4]
- **In 1985:** ophthalmologists Aran Safir and Leonard Flom confirmed that irises cannot be similar.
- **In 1985:** Using hand geometry to document personality.[4]
- **In 1994:** Establishing the first automatic fingerprint recognition system.[4]
- **In 2000:** Publishing the first paper describing the use of blood vessels to identify people. This technique uses the shape of blood vessels under the skin on the back of the hands to achieve national recognition.[4]

Nowadays , biometrics are used and developed in almost every field. Most members of our society are using biometrics on a daily basis, fingerprints and face recognition are used to unlock phones and pc’s. In the last few years , biometric technology has become a necessity for individuals because it provides a more secure solution which guarantees privacy while using different devices. Researchers are still improving the use of biometrics by enhancing speed ,accuracy and the ease to use, they also consider new or unknown types like hand vein or footprint. every biometric type has its weakness or “blind spot”, even the most reliable ones have cases when it can be used like injuries for fingerprints or illness in case of Iris.

2.3 characteristics and performance:

2.3.1 characteristics:

• **Universality**: The availability of attributes for each person in order to reduce the Failure To Acquire rate, i.e. the rate at which a biometric system is unable to acquire or extract biometric templates from a person in the target population.

• **Distinctiveness**: The singularity of biometric features induced by genetic variety, as well as random factors impacting embryo development, has a significant impact on interpersonal variability. Twin studies are frequently used to judge uniqueness performance.

• **Permanence**: the biometric characteristics do not change over long periods of time, they are considered permanent. Weight changes, for example, may have an impact on pressure-based footprint elements. According to empirical data, ridge-based fingerprint features are known to be stable.

• **Collectability**: Biometrics are anticipated to simplify authentication, requiring easily measurable and quantifiable traits. Biometrics with great collectability (facial, signature, or hand geometry) usually have high acceptance.

• **Performance**: Such as the system's computational or resource demands. Inspecting biometric system assessment in, a compromise between performance and acceptability can be established, hence legitimising biometric diversity.

• **Acceptability**: Negative associations with a specific biometric are usually undesirable. However, high uniqueness can often come at the expense of lesser acceptability, as in the case of iris, retinal scan, or fingerprint biometrics, due to more complex acquisition, related to criminal investigation, and privacy concerns.

• **Circumvention**: Intruders should be unable to deceive the biometric system. This is difficult to do for some biometrics, like signatures or faces.

2.3.2 performance:

Aside from the biometric features, a practical biometric system should be able to meet the stated recognition accuracy, speed, and resource requirements, as well as be safe and resistant to various attacks. Table 1 shows biometric technologies and its compatibility with every one of previous characteristics. [5]

A similarity match score is used to demonstrate how similar two feature sets are. A higher score indicates that the two biometric traits under evaluation are from the same person. False Non-Match Rate (FNMR) or False Reject Rate (FRR) and False Match Rate (FMR) or False Accept Rate (FAR) are the two fundamental methodologies for determining the accuracy of a biometric system. It is also regarded as one of the two major faults of a biometric system. The chance of two samples of the same biometric feature from the same user being labelled as non-match is referred to as FNMR [3].

Table 1 : Types of authentication and their characteristics:

Types of biometric	**Unevar -sality**	**Perfor-mance**	**Unique -ness**	**Collect -ability**	**Perma-nence**	**Accept-ability**	**Circum-vention**
Face	H	L	H	H	L	H	L
Fingerprint	M	H	M	M	H	M	H
Hand geometry	M	M	H	H	M	M	M
Keystroke Dynamics	L	L	M	M	L	M	M
Hand Vein	M	M	M	M	M	M	H
Iris	H	H	H	M	H	L	H
Ritina	H	H	M	L	H	L	H
Signature	L	L	L	H	L	H	L
Voice	M	L	L	M	L	H	L
Facial Thermo gram	H	H	L	H	M	H	M
DNA	H	H	H	L	H	L	L
H=High, M=Medium, L=Low							

2.4 Biometric types:

According to the definition of biometrics, there are two main types that are used to identify individuals: physiological and behavioural.

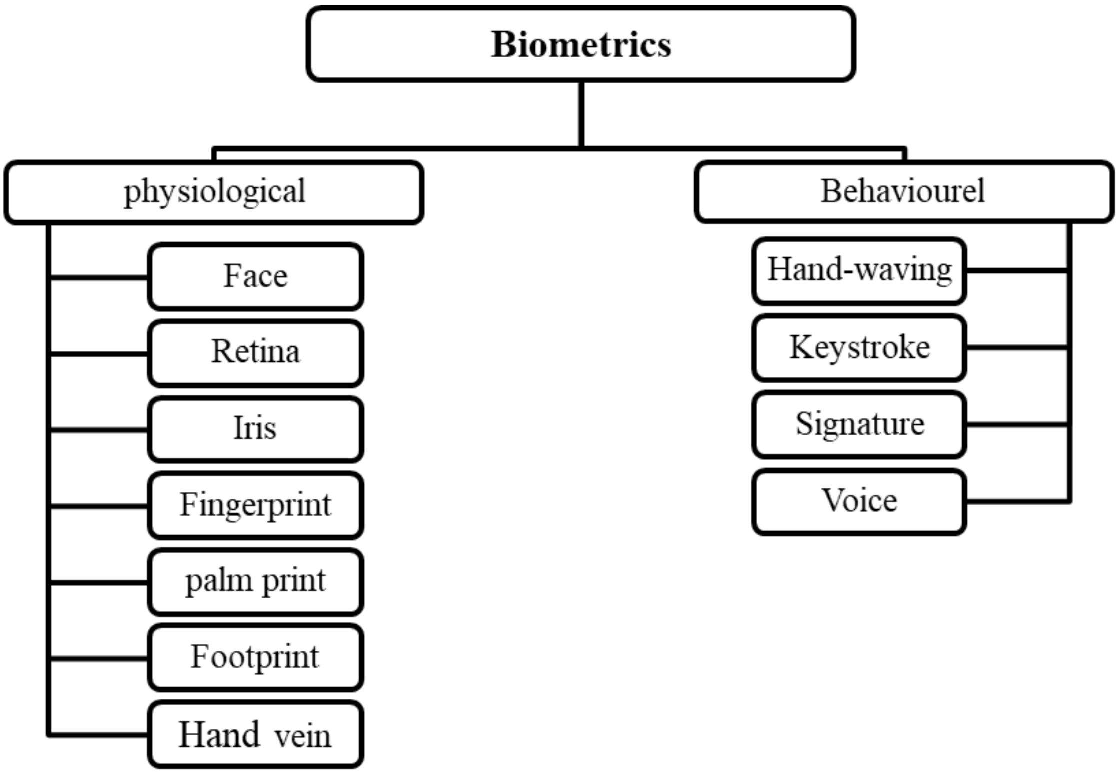

Figure 2.3 : Types of biometric authentication

2.4.1 Behavioral Biometrics:

Like the names suggest, behavioural characteristics are related to one's behaviour, which makes them prone to change depending on changes like accidents, ageing, and their mood. However, we use some of them in our daily lives, like signatures and less used ones like voice recognition or key strikes.

a) Dynamic signature :

It is believed that the way in which a person writes his or her name is thought to be distinctive to that person and, as such, could provide a viable means of biometric recognition. Dynamic signature recognition is a way of assessing an individual's signature that is automated .

Signature verification is primarily accomplished through the use of a special pen (or stylus) and writing tablet, which are linked to a computer for processing and verification. To begin the data gathering phase of registration, the participant must sign his or her name on the writing tablet many times.

After collecting the data, the signature verification system extracts the writer's behavioural characteristics, such as how long it took the person to sign ; how much pressure was that were used; how quickly they moved when signing ; the total size of the signature; and the amount and different direction of the strokes in the signature, and uses this data in comparisons of the live signature to the enrollment template for the verification of enrollment claim.[1]

This type of authentication considered to have a low accuracy because many reasons that affect the its process, among them :

- In case of injuries in the dominant hand, it is not possible for the person to do the same signature with his/her other hand.
- It can be forgotten due to ageing or even stress.
- Its process takes a long time when collecting which makes it rather inconvenient.

b) Voice recognition:

Speaker recognition, often known as voice recognition, is a biometric modality that uses an individual's voice to identify them. The speaker recognition process is based on factors impacted by both the physical structure of an individual's vocal cord and the individual's behavioural traits .

A microphone is used to record a person's voice in speaker recognition or voice authentication. The recorded voice must be digitised for authentication. 'The user can acquire speech by enunciating a known speaking (text independent) or text (text dependent)'. In the latter situation, the wording can be prompted or determined by the system. The text can be read sequentially or continuously as a whole text. Furthermore, in order to create a voice template, the acquired speech is improved and distinctive elements are retrieved. (Yun 2002)

Because certain features of an individual's voice are based on the shape and size of their vocal tracts, mouth, nasal cavities, lips, and so on, voice is frequently classified as a combination of a behavioural and a physiological biometric.From a biometrics standpoint, there are two types of voice/speaker recognition systems: text dependent and text independent systems. In a text-based system, the user speaks a specific, prepared pass phrase, such as a sequence of integers. When enrolling in such a system, the user may be asked to repeat the pass phrase several times in order for the algorithm to adjust for intra-class variation. As a result, the enrolment process takes longer, although it is considered to result in more accuracy.

Because the voice is a popular mode of communication, when combined with a large telephone network and microphones, the cost of voice authentication can be very low, and the system itself can be very small.

Voice recognition is one the most efficient ways of biometric recognition for its ease-to-use and low cost. However, there is some factors that lower its efficiency like:

- It depends on the well being of the person, especially his/her voice cords.
- Some of the old and common methods have a high possibility of breach, which make it unpopular among people.
- For identification, it requires the lack of noise which makes it unusable for daily tasks like smartphones.

c) Keystrokes.

d) Gait.

2.4.2 Physiological Biometrics:

The physiological characteristics are more stable and precise, such as face, fingerprint, hand geometry, iris. These biometric traits are essentially fixed and do not change over time.

a) Fingerprint :

The idea of using fingerprints for identifying individuals started from ancient civilisation. It was until the 19th century that the idea of there being no two individuals with the same fingerprint became accepted.

Nowadays, fingerprints are the most used method of authentication because it is easy, accurate and fast. It has become a daily routine to use our fingerprints for identification in unlocking our smartphones, voting, bank's transaction..etc.

Fingerprint recognition uses the unique patterns that every individual have.and its process became an easy task over the years, there are many methods to extract and save the patterns, but they all have the same principle as the process of the image of the finger and separate the needed patterns.

Fingerprints are the earliest, most effective, and most widely used biometric feature for identifying people. Fingerprints have a regular texture pattern made up of ridges and valleys.

The focused feature spots in a fingerprint are the minutiae, which are ridge ends and ridge bifurcation (Figure 2.4).

There are a considerable amount of minutiae in every fingerprint (Figure 2.5.). There are multiple studies in the factors that create these types like sex, genes … etc.

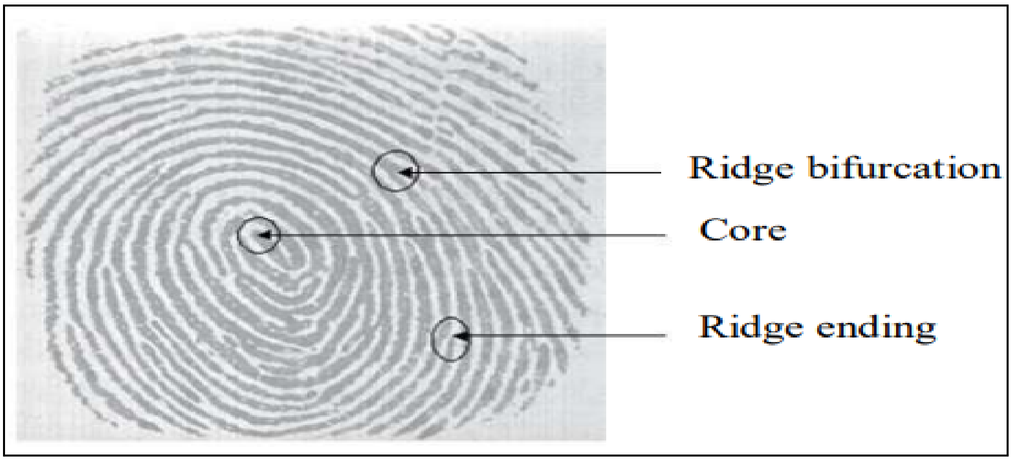

Figure 2.4 : A fingerprint image with core and minutiae points marked on it. The global structure is the ridge pattern along with the core and delta points. Local structures are characterised by minutiae points.

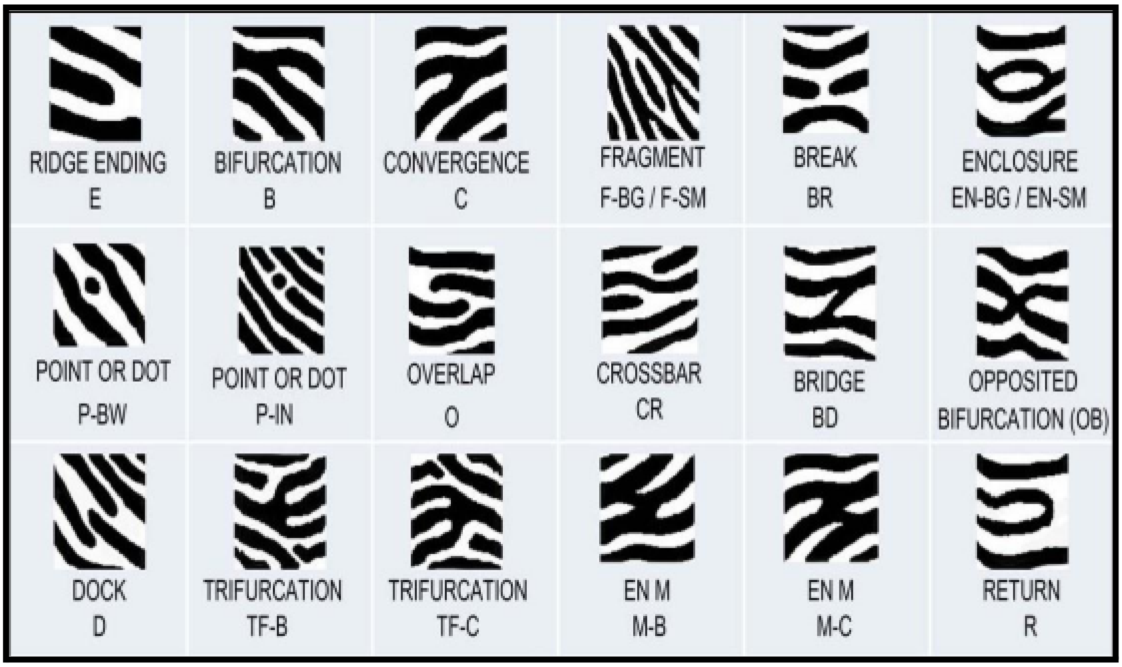

Figure 2.5 : Some types of minutiae (Gutiérrez-Redomero et al. 2011) .

The skin on the surface of a fingertip consists of raised folds of skin, known as ridges, and these ridges are separated by valleys. The pattern of ridges and valleys on a fingertip represents a fingerprint, which is what is used in biometric recognition. The three major fingerprint features used for pattern recognition are arches, loops and whorls(Figure 2.6), one of which is found on a given fingerprint. Two other major features may also be used for recognition, i.e. the core and delta. The core is the centre point of a particular fingerprint pattern and the delta is a point from which three patterns deviate. The core and the delta can be used as landmarks to orient two fingerprints for matching; however, it should be noted that these features are not found on all fingerprints.

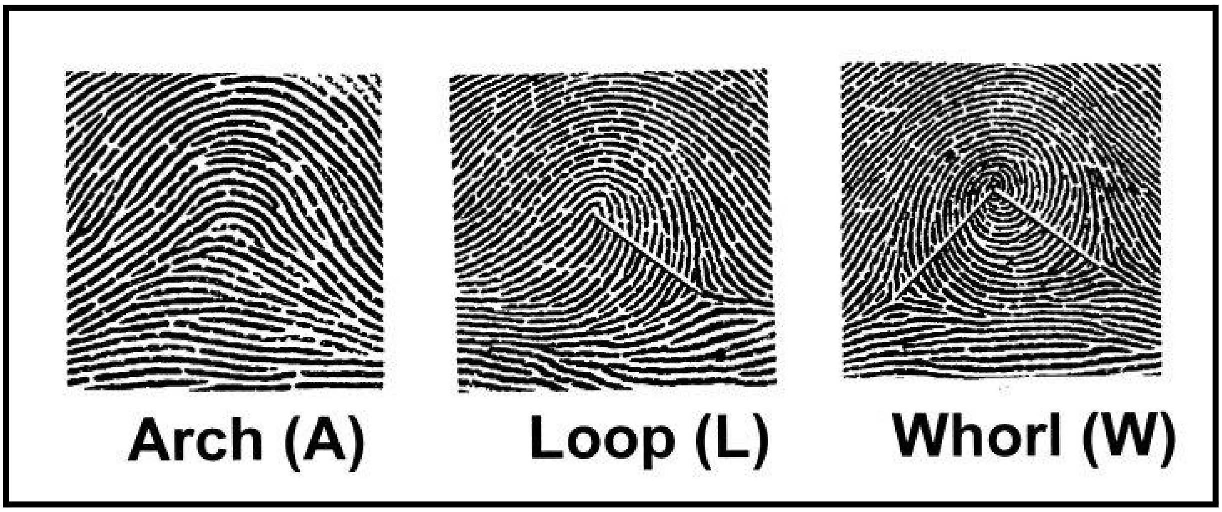

Figure 2.6 : Basic fingerprint patterns.

Even after the development in sensor's technology, the process of using fingerprints as a way of identification or authentication still has the same steps with every type of sensor (optical, touchless …etc).There are three ways (steps) of using fingerprint :

- **Enrolment** :

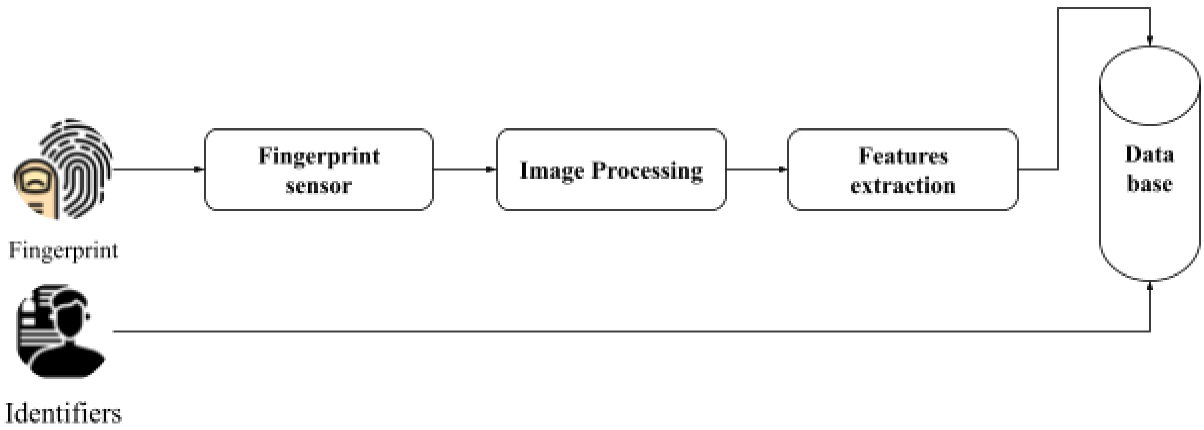

Figure 2.7: Enrollment phase diagram

- **Verification:**

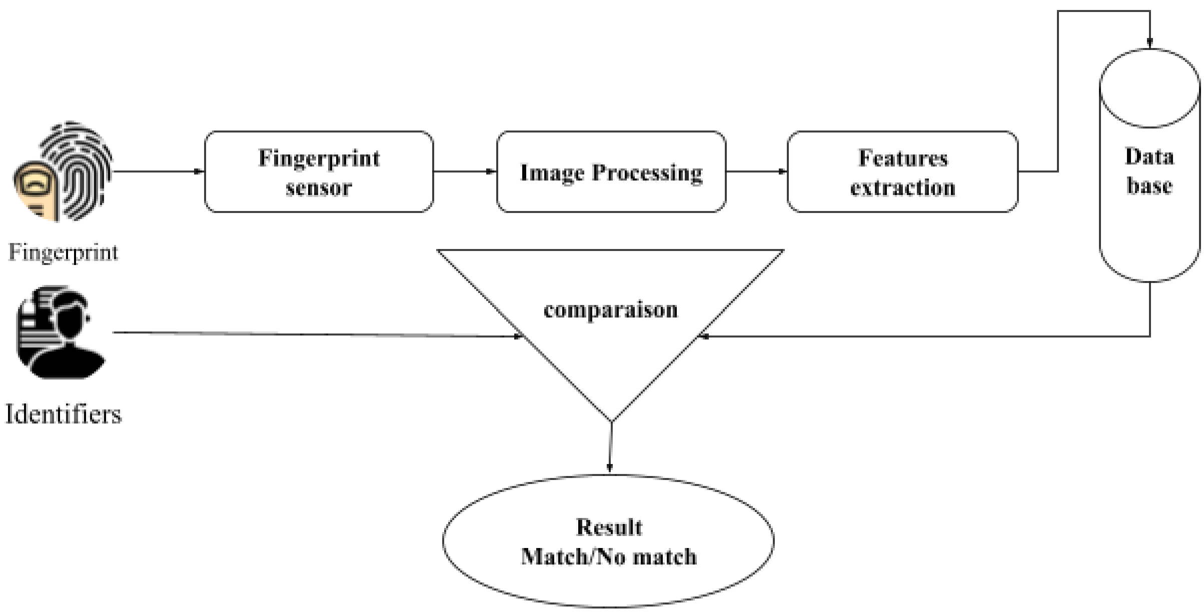

Figure 2.8: Verification phase diagram

- **Authentication :**

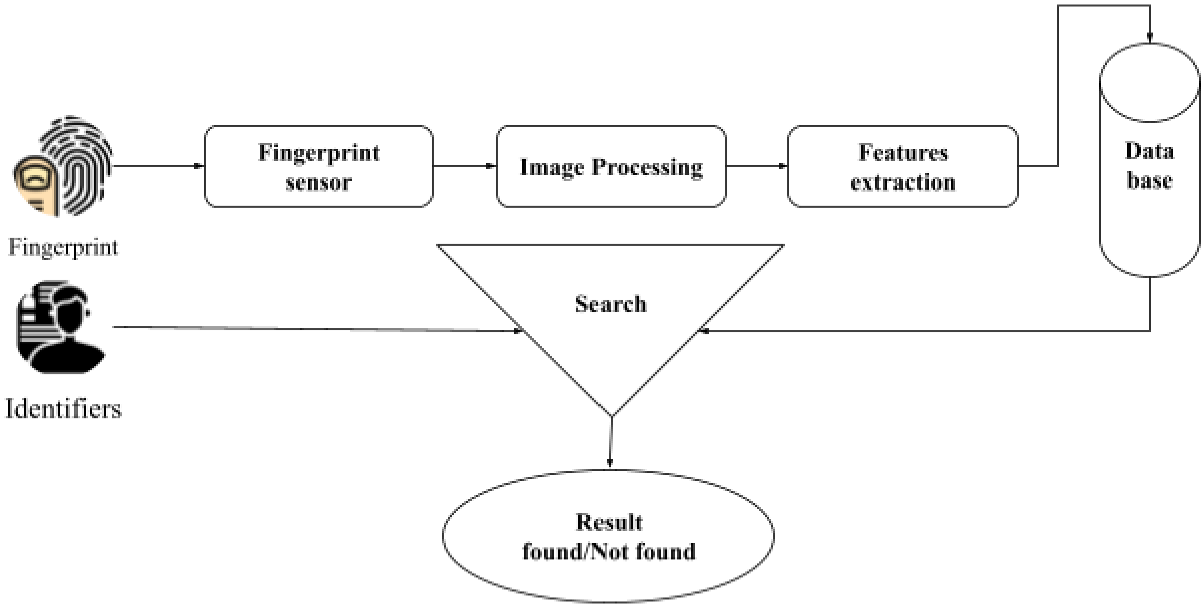

Figure 2.9: Authentication phase diagram

The advancement of fingerprint scanning technologies. In two ways, fingerprint sensors have evolved. On the one hand, they have become smaller and less expensive, allowing them to be embedded in devices such as laptops or mobile phones. While some apps continue to use a large surface area fingerprint sensor (for collecting a full fingerprint impression, resulting in improved accuracy), they also include a number of additional features. A common example is the slap sensor employed in the US-VISIT program, which can collect impressions of multiple fingers at the same time, allowing for the quick capture of tenprints. (Figure 2.10)

Figure 2.10 : Evolution of fingerprint sensors

Nowadays, fingerprint authentication has become widely used in almost every part of our lives, starting with phones and all personal electronic devices, unlocking our home door, voting, bank transactions and even in hospitals.(Figure 2.11)

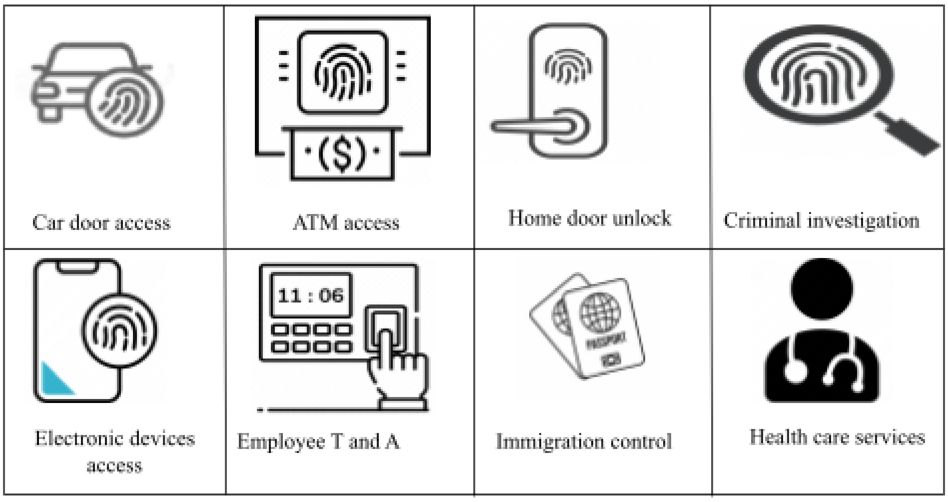

Figure 2.11 : Most common utilisations of fingerprint

In general, fingerprint recognition can attain high accuracy for both verification and identification. It is a popular product for consumers due to its low cost and compactness. However, the sensor is unable to collect acceptable quality fingerprint photos for those with extremely dry or moist skin. Furthermore, in order to achieve constant functioning, the sensor must be kept clean.

Fingerprint authentication is the most used, efficient and convenient method due to its location in the human body (hands), because the hands are the most free part of the body. Some challenges arose as the underlying technology advanced to new heights as :

- Unacceptance from people to voluntarily give their fingerprint out of fear.
- In most countries, taking all fingerprints is practically impossible because of that it is hard to use fingerprint authentication in domains like crime investigation.

Even after all that, fingerprint is the most popular way of authentication, and the range of its uses are becoming bigger by the day. Even the governments that are against using it now became more interested in it.

b) Iris recognition:

The iris is a muscle within the eye that controls the quantity of light that enters the eye by regulating the size of the pupil. It is the coloured component of the eye, with the amount of melatonin pigment within the muscle determining the colour (Figure 2.12).

The act of recognizing a person by examining the random pattern of the iris (Figure 2.13) is commonly referred to as iris recognition. The automated method of iris identification is quite new, having only been patented in 1994.[6]

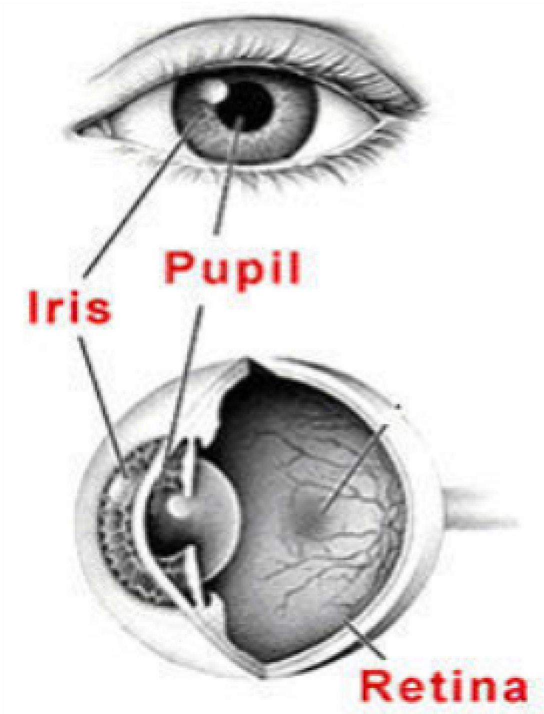

Figure 2.12: Human eye structure.

Figure 2.13 : Colour portion of the eye

Iris recognition process consist of three main parts (sub-systems) everyone is responsible of a stage :

- **Image acquisition-capturing eye image :**
  Because the feature extraction stage is dependent on the image quality, the iris image should be rich in iris texture. As a result, the image is captured by a 3CCD camera located around 9 cm from the user's eye. The distance between the user and the light source is approximately 12 cm. Figure 1 depicts the image acquisition setup. When capturing the photograph, the following considerations were taken into account:
  - High resolution and sharpness are required for reliable detection of outer and inner circle boundaries.
  - Proper lighting: A diffused light system is employed to avoid the spotlight effect [7].

  This part of the process is carried mostly by the hardware. Capturing the image of the iris needs a certain amount of light. Therefore, every iris recognition system has a source of light. In addition, the system needs CCD camera and a frame grabber sub-system(software).Figure 2.14
  Figuier 1.15 explains the Iris recognition process.

  An eye image will be used as the system's input, and its output will be an iris template that represents the iris region mathematically.[6] with few steps between the image taken and the template obtained. Figure 2.15

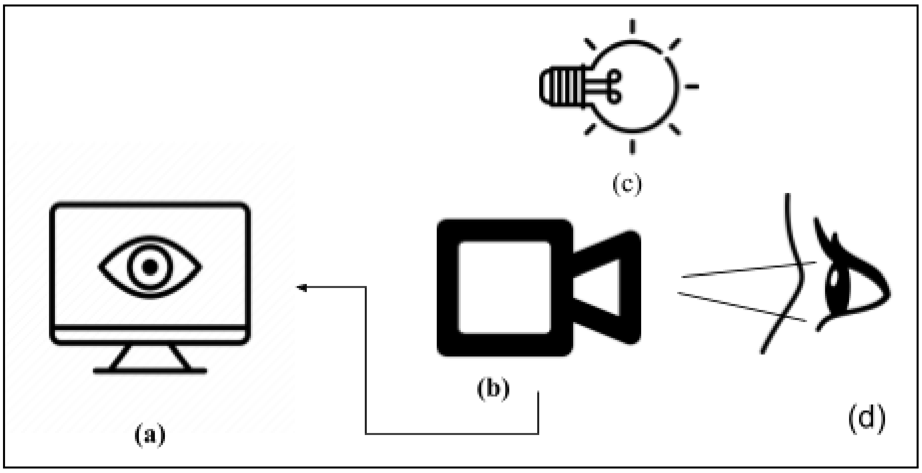

Figure 2.14 : Image acquisition system.System with frame grabber ,(b) CCD camera ,(c) light source,(d) user

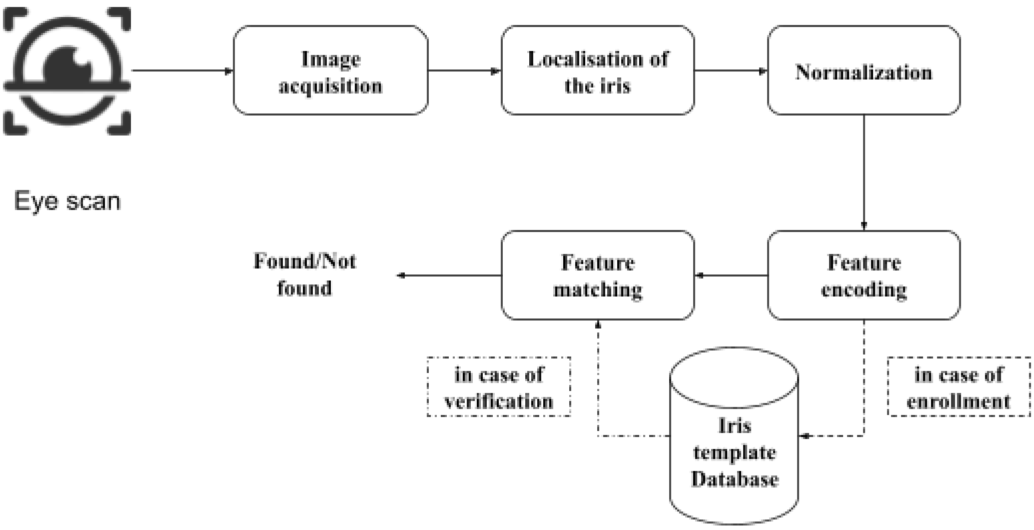

Figure 2.15 : Iris recognition schematic diagram

- **Segmentation :**
  Integro-Differential Operators are used to segment the iris.
  The method of automatically recognizing the pupil and limbus boundaries of an iris in a given image is referred to as iris segmentation . This procedure aids in the extraction of features from the iris' discriminative texture while excluding the surrounding regions. Iris segmentation is critical to an iris recognition system's success. This is because faulty segmentation might result in incorrect feature extraction from less discriminative regions such as sclera, eyelids, eyelashes, pupil, and so on, lowering recognition performance.[8]

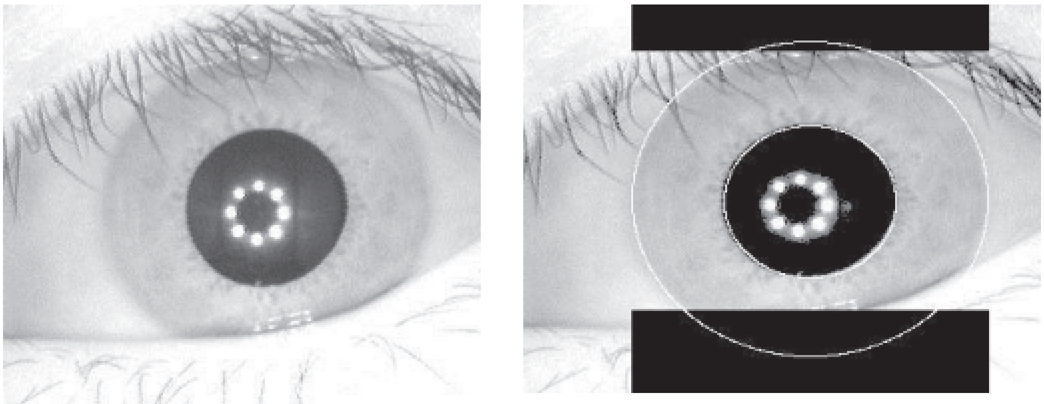

Figure 2.16 : Image of iris before and after segmentation.

- **Normalisation**:
  This stage creates a dimensionally consistent representation of the iris region.The image of the iris is obtained by decreasing mistakes in the normalisation stage, and a rectangular shape of segmented iris is created. The normalising procedure is depicted in Figure 2.17.
  During the verification stage, a scheme is used to detect and match the iris code in the database to the live iris code using the Hough Transform. However, because the Integro-Differential Operator lacks this property, another normalisation technique, such as the Gabor Wavelet, must be combined with it to acquire the iris information.
  The normalisation technique's output is saved in the database in two forms: pixel values and iris codes.[8]

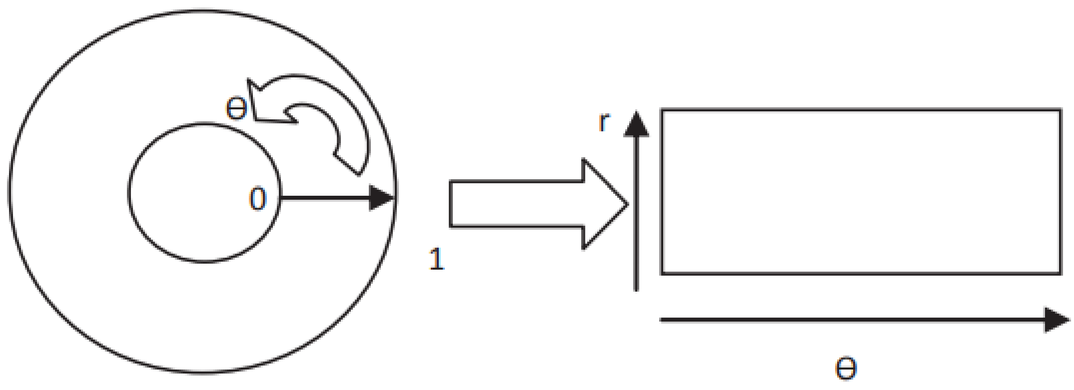

Figure 2.17: Normalisation technique

- **Feature encoding :**
  The generation of the iris code is the final process.The main distinguishing element of the iris pattern is extracted for this purpose. Because phase angles are assigned regardless of image contrast, only the phase information in the pattern is employed.[10] Amplitude information is not used because it is dependent on external influences. According to Daugman, phase information is extracted using 2D Gabor wavelets.[9]
  An easier way of using the Gabor filter is by breaking up the 2D normalised pattern into a number of 1D wavelets, and then these signals are convolved with 1D Gabor wavelets.

c) Face recognition

The face recognition method is based on recognizing the facial structure because the distances between the eyes, nose, mouth, and so on are unique to the face person and have a very low possibility of recurring in another person. Face recognition is the mapping of a person's face and remembering basic data about its circumference and distances between its components, and while scanning, an attempt is made to find the closest match.

A face image can be acquired using a normal camera. It is the most common biometric for identity authentication. The two main approaches that are used to perform face recognition are holistic or global approach and feature-based approach (Chellappa et al. 1995).

- **Feature-based approach :**
  The feature-based technique is based on identifying specific fiducial spots on the face that are less vulnerable to change, such as the points surrounding one's cheekbones, the side of the nose and mouth, points near the eyes, and so on. The coordinates of these points are used to calculate the geometrical relationships between them. Local analysis can also be performed on the regions surrounding the locations. The findings of the local processing at the fiducial locations are then gathered and integrated to provide the overall face recognition. Because feature point identification comes before analysis, the system is resistant to image position fluctuations. However, automatic identification of fiduciary points is insufficiently constant and reliable to produce a high accuracy ratio for face recognition.
- **Holistic approach :**
  As seen in fig 1.17, the holistic technique analyses the complete facial image at the same time without localising the individual points. The sort of technology employed in this technique varies, such as neural networks, statistical analysis, or transformations. The holistic method has the advantage of utilising the entire face. In general, this produces more accurate recognition results. However, because such a strategy is sensitive to fluctuations in scale and position, substantial training data sets are required.

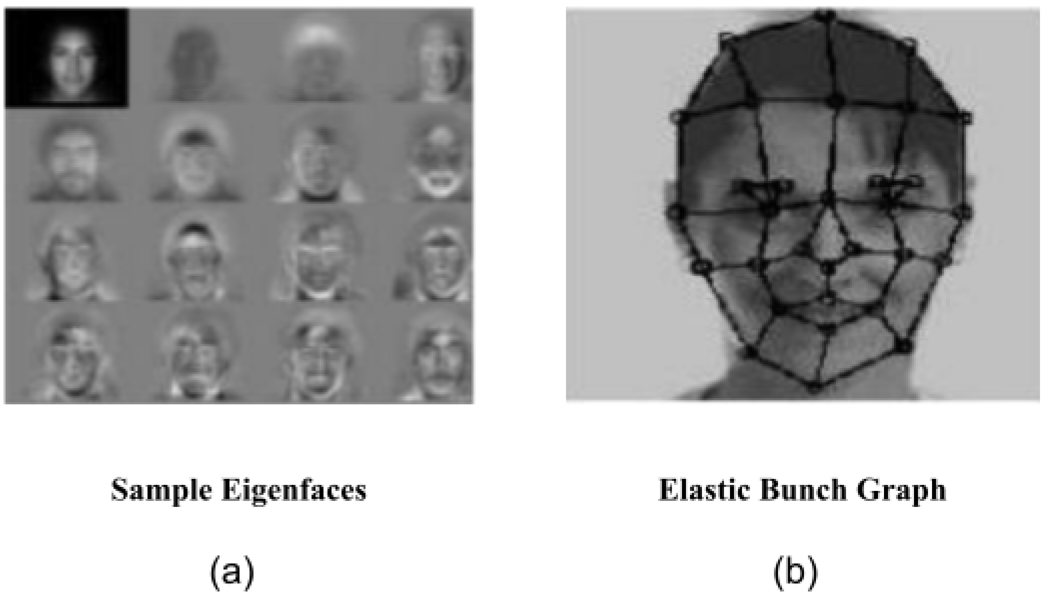

Figure 2.18: Examples of Face Recognition Technique (adopted from(Yun 2002), pp.86))

d) Hand geometry

Hand geometry is the geometric structure of the hand that is made up of the lengths of fingers, widths of fingers, and width of a palm, among other things. A hand geometry system has the advantage of being a reasonably basic method that can employ low resolution photos and gives high efficiency with high user approval.

Hand geometry features are extracted from an image by 3 steps as follows: image acquisition, image pre-processing and feature extraction.

For image acquisition, it demand multiple hand posture for the system to have enough data for the next step.Figure 2.19

Figure 2.20 shows an example of image processing, the result obtained after image processing .Because the acquired image is in colour, it is transformed to grayscale. The median filter is used to eliminate noise from an image. There is a visible difference in intensity between the hand and the background due to the black background. As a result, the image's histogram is bimodal. By thresholding, the image can be simply turned to a binary image.The Otsu method is used to automatically compute the threshold value.[10]

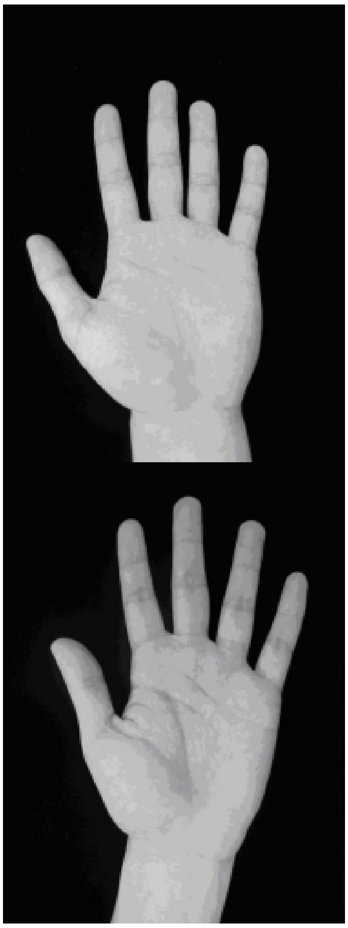

Figure 2.19: Multiple hand poses

Figure 2.20: Example of image processing

e) Ear shape :

Iannarelli presented a biometric recognition system based on twelve ear characteristics measures. After being aligned and scaled throughout development, photographs of the right ear were to be taken and then registered. This allowed the images to be normalised in size and orientation, making them easily compared. Measurements of the distance between the various ear features in 3 mm increments were saved, along with sex and racial information [11]. But due to the significance of precisely identifying the sites of measurement, this method has been widely regarded as inadequate for machine vision.

A wide range of strategies for ear recognition, identification, and verification have been developed over the years. However, significant barriers to the precise and adequate acquisition of ear biometrics have persisted due to the difficulty in measuring the ear's anatomy details and the easy and common hiding of the ear area. As a result, ear biometrics now play only a modest and supplementary function in identification and verification, including forensic science applications.

As we've already stated, ear biometrics require a rather large number of challenges that must be addressed before the ear may be properly used for identification and verification. These difficulties include potential ear camouflage, images and schematics produced at angles that obscure crucial ear features and traits, and the effects of age[12].

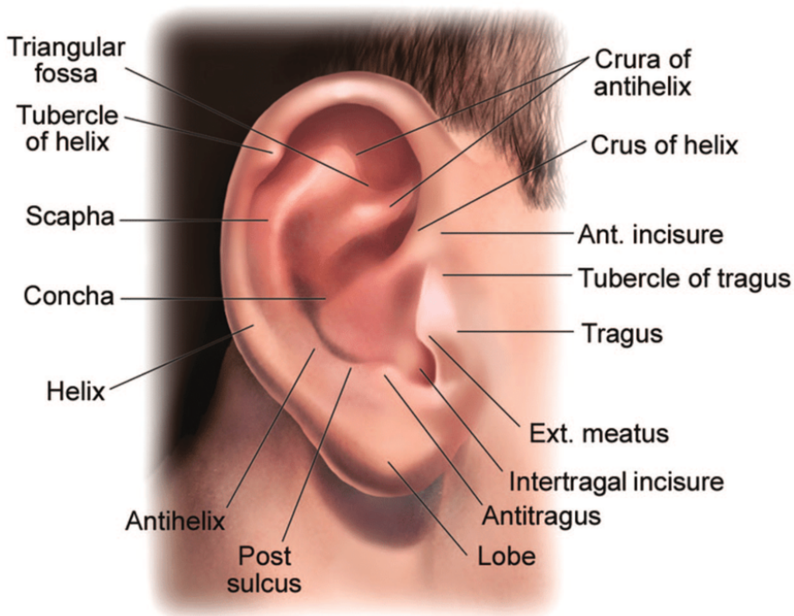

Figure 2.21 : External ear anatomy [14]

Eventually, 3D imaging techniques appear to offer another option to deliver extremely reliable ear biometrics for effective recognition and identification.Recent research have demonstrated that such 3D imaging approaches for ear biometrics have a rank-1 identification rate of around 95%.Even though 3D approaches do not add considerably more ear biometrics to 2D imaging, they can improve the accuracy of the features being recorded, leading to improved registration. These solutions, however, are extremely dependent on the lighting and shading of the collected images and necessitate preprocessing to remove artefacts presented by the 3D sensor.
While it has been stated that, among existing biometrics qualities, ear biometrics, together with iris and fingerprint biometrics, are particularly viable and robust.

f) DNA :

Every human being can be identified by genetic variation present in his or her DNA. Except for identical twins, who have the same DNA pattern, DNA (DeoxyriboNucleic Acid) is the one-dimensional ultimate unique code for one's individuality. DNA is currently mostly used in forensic applications to identify people. In forensics, the first stage of DNA analysis is the acquisition of a DNA sample (a collection of cells) from a crime scene, such as blood or hair. After isolating the DNA from this sample, the targeted loci are amplified, and the DNA is sliced and sorted so that the distinct sections are ordered by size, i.e. the number of repeating units. When transcribed, the resultant DNA profile is a computerised representation of the required areas of variability, with the amount of repeat units at each locus specified [15].
Double helical DNA is made up of two complementary, antiparallel polydeoxyribonucleotide strands that are linked together by particular hydrogen bonding interactions between nucleotide bases. The helical grooves are defined by the sugar phosphate backbone of paired 3 strands, within which the edges of the heterocyclic bases are revealed.The biologically significant B-form structure of DNA.A double helix has a shallow, wide major groove and a deep, narrow minor groove. (Figure 2.22) The chemical characteristics of the molecular surfaces provided by a specific DNA sequence in either groove are unique, and serve as the foundation for molecular recognition by small molecules and proteins.[16]

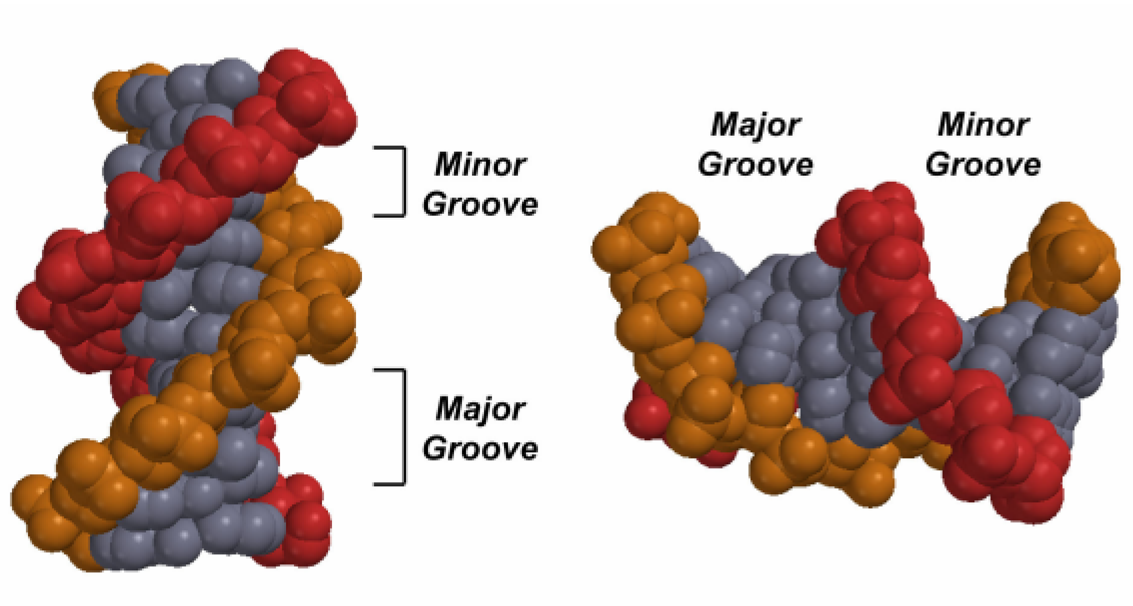

Figure 2.22 : Structure of DNA

We mentioned several types of biometrics, so we evaluate them according to the types of authentication. We find that the highest biometrics in terms of accuracy are the fingerprint and the retina of the eye, while the average ones include hand geometry, voice, iris and signature, while the weakest is the face.
As for the ease of use, we find that the hand and face geometry are the easiest and relatively least, the fingerprint, the iris of the eye, the signature, and the least, the least, the retina of the eye due to its difficulty and inconvenience to use
In this context, we shed light in this note on another type of biometrics, which is the **footprint.**

2.5 Footprint :

Every human being has unique biometric characteristics that help identify him and him alone. Some are widely known, as for fingerprint, iris and DNA; and some are barely known like ear-shape, palm pattern, hand geometry and **footprint.** Even though infant footprints have been captured for many years, the use of footprint for automated biometric recognition is a relatively new research topic.

Eryun Liu conducted research into infant recognition in 2017 examining 54 subjects over three collections from 2 days to 6 months old and saw reasonable recognition rates in footprint recognition during this time [17].

2.5.1 Definition:

The term **"footprints"** is used in more than one meaning therefore, we present some used definitions :

a) The general definition is the impressions or images left behind by a person walking or running. Or the mark left in the ground that helps track the course of a human being or animals.
b) Some use the term **"Footprints"** for describing the impact of human beings in the earth's ecosystem.

The definition that we are interested in is :

footprint is unique patterns in every human under foot (**Figure 2.23**), that is different for every individual which makes it a valid way for **biometric authentication**.

Figure 2.23 : Scanned image of underfoot

2.5.2 current usages :

In the last years, human developed every possible way of recognition and identifying individuals, for that know we use in daily base all kind of biometrics. some of the biometrics did not merge in our life because it is hard or inconvenient to use like ear shape, hand geometry and footprint.

For its inconvenience, footprints are not used on a large scale like fingerprints or face recognition because in adult life the feet are covered,dirty or wet. Therefore, footprint didn't have its share of development like other biometrics.However, It's another case for children especially babies at their early days of life. Taking fingerprints become very challenging for babies in contrary, footprints become a solution for identifying babies and other usages.There are countries (USA, UK …) that uses footprints for two main reasons :

- **Birth certificate :** Most hospitals in the USA (for example) use footprint in birth certificates but not in an automated way by using either traditional ink and paper or the most used method recently by using inkless printing which uses inkless pads and special paper (**Figure 2.24**).

Figure 2.24 : Taking a baby's foot print using inkless printing

- **crime solving :** in many crime scenes, the culprit out of rush or negligence leaves his footprint. Therefore, investigators had to explore the option of making a footprint as evidence for identifying the culprit. It is hard to say when it started, the accident that was considered the first happened at a Scottish bakery in 1952 when a safe-cracker was identified by the footprints he left in flour (**Figure 2.25**)

Figure 2.25: Footprint taking as evidence in crime scene

It's common that cases get solved after obtaining a footprint from the crime scene.Therefore, police departments all around the world urge researchers to develop the technology relevant to reading footprints and making a database to simplify their work on similar crimes.

Other countries like Japan started studies about footprint verification. They intend to use that technologie to identify bodies after a natural disaster like earthquake or tsunami which causes a large number of deaths. In many cases the bodies found after are not completed like finding just a lower part of bodies which make identifying the victim hard. They thought that having a way of identifying victims with their footprints will solve most of the problems of identifying individuals after natural disasters.

- **2.5.3 characteristics of footprint**

Every human foot has unique patterns in more than one place and just like the hand, the foot has toes and a palm (sole). We found the most efficient places to use for identification are toes and the area beneath the big toe.

a) **The area under the big toe :**

This area has patterns and ridges that are unique for every human which allows it to be a way of biometric recognition (**Figure 2.26**). These patterns are similar to fingerprints which make it possible to scan and register them with most of fingerprint's scanner. The fact that these patterns exist in the foot is very convenient to obtain from babies and they occupy a relatively big surface which helps with the clearness of the image taken.

Figure 2.26: Example of the patterns under big toe

Aging is one of the most important factors in biometric studies because it changes its characteristic but the most important change for this case is the area’s size. When the change occurs in the size it requires a bigger scanner for older age especially in case of baby to children (because of their growth speed). For that, we intend to use the area as a helping tool to make a better accuracy.

b) Toe print :

Toe print is another possible physiological feature of a person for the identification task. Toe prints have similar ridge patterns to fingerprint impressions but also include distinctive traits (minutiae points) that help distinguish one person's identity from another. In the past, children's footprints were used to verify their identity. [17].

The use case of footprint for grown-up children and adults is not feasible as the size limitation of acquisition sensors. Nevertheless, toe print can easily be acquired from standard fingerprint sensors, making toe print one of the possible biometric traits.

Toe print applications for biometric identification/verification might be crucial for people with varying capacities. Because the area of a toe print (big toe print) is bigger than that of a fingerprint, it may carry more information (e.g., more minutiae points) than a fingerprint.[18].

obtaining a toe print can be done by any fingerprint scanner for that, researchers dropped the idea of developing a toe print scanner and almost all the known research was done by fingerprint scanners.

Figure 2.27: Acquisition of toe print using Futronic FS60 optical fingerprint sensor

2.6 Biometrics in health care:

Nowadays, e-Health includes a wide range of services and systems at the cutting edge of healthcare and information technology:

- **Telemedicine** : remote health care delivery via telecommunications and information technology.
- **Electronic health records** : electronic health information about a patient or individual.
- **Consumer health informatics** : the use of medical informatics to analyse consumer information needs.
- **Health knowledge management** : capturing, describing, organising, sharing, and effectively using healthcare knowledge.
- **Medical decision support systems** : interactive expert systems that assist physicians in making medical decisions. [19]

Biometrics technologies are increasingly being seen as an approach of avoiding unauthorised use of system resources, managing access to information systems, and assuring the security of financial and patient records in the healthcare industry.

In general, adopting biometric technology as an access control and authentication approach improves patient privacy protection. By incorporating accurate authentication technology, unauthorised access to sensitive information is reduced by restricting delegation of access rights and impersonation of individuals; additionally, it eliminates the cost associated with password maintenance, reduces insurance claim fraud, and becomes a long-term solution for access system management.

Chapter 03 :

Newborn identification through footprint

Chapter 03 : Newborn identification through footprint

To avoid critical problems such as mixing or kidnapping babies or even for the lost ones Identification of a newborn just after birth is one of the most important challenges in both health care and biometrics. To avoid critical problems such as mixing or kidnapping babies, researchers tried various approaches to solve this problem. The first aim to solve this issue was fingerprint but there were obstacles that are almost impossible to overcome because of the baby's skin nature. Iris was not considered for its hard and relatively long process, especially for babies who tend to close their eyes most of the time, and face recognition is not an option due to the massive change in babies face structures in a very short time compared to adults or even mature children. Now every hospital uses the most basic methods for identification which are less precise and secure then biometric identifications.

3.1 Current methods :

Hospitals everywhere around the world use an ID band (Bracelet) for the identification of a newborn. There are multiple shapes and colors of bracelets in the hospitals .Figure 3.1 shows different types of ID band , some come with colors to separate sex and some are printed with names and also a bar code. and for some countries like USA hospitals use a footprint with ink in addition to the ID band . For the footprinting with ink is more like a sentimental act for the parents and second phase of verification, which is not efficient to be called identification type.

However, the ID band is considered the main tool to distinguish babies from each other after they are born. Also to define their mothers in case they get separated from them for medical interference or any other reason. There are a lot of weaknesses in identifying babies with the ID band that oppose the purpose of identification and sometimes it helps with switching identities. these are the most important issue in ID band identification :

- It depends on the health agent's conscience to decide whether to do the right thing.
- It can be cut and replaced with another name.
- In case of two babies with the same name on the ID band it does not work and becomes useless.
- Have a low accuracy and safety in the use.
- It is permanent, once the baby leaves hospitals it becomes useless which means it lasts just for a few hours which is a really short time for identification.

In other hospitals, withdraw genetic material that makes the DNA examination possible and to run a DNA test in case of a problem occurring. DNA has high precision for identifying babies especially when one or both of the parents' genetic material are provided. On the other hand DNA is very costly to use and it is not a real time application. In addition, DNA tests require the presence of sophisticated laboratory equipment and delicate processes.

(a) (b)

Figure 3.1 : Types of ID band (bracelet)

(a): Simple bracelet, (b): Bracelet with printed name and barcode.

3.2 Suggested solutions :

For the importance of the subject of identifying newborns, researchers proposed multiple solutions for this issue. As we stated before the currently used methods have problems with being precise, practical and secure. For that many researchers went to a more efficient way of identification that is more accurate and is more secure.

Biometric identification is the most reliable method for identifying individuals. For adults, biometric identification has shown excellent results and because of the outstanding results with adults some biometric types were suggested for children.

3.2.1 Fingerprint :

Despite the interest in children's fingerprints as a genuine biometric feature, relatively few systems are equipped to handle such information. Although there may be other reasons why it is not commonly employed, one of the most serious issues that the research community has is a lack of studies on the use of children's fingerprints for automatic comparison. One obvious cause is the paucity of systems in the world that collect fingerprints from both minors and adults [20].

Recent studies showed that even with developed technology it is hard to obtain valid fingerprints from new born that suit the standard of the identification. [20] made a research on fingerprint from baby to adult and the difference between the image obtained from different ages from newborn, babies months old and children from 1 to 5 years to adults. The study showed that the fingerprints taken from children under twelve months old are not valid for identification due to multiple reasons such as the hardness of image acquisition and the clarity of ridges. Figure 3.2 shows the difference between images of fingerprints taken from different ages.

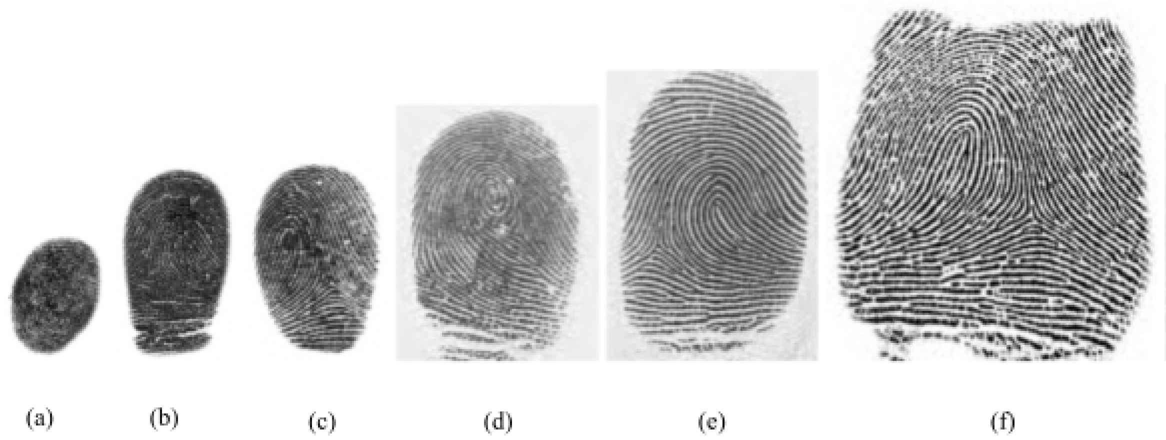

Figure 3.2 : Fingerprints taken from multiple ages

(a): new born, (b): month old, (c) : 1 year and half old, (d): 5 years, (e): 9 years, (f): adult.

In conclusion , Using a newborn's fingerprint to identify them raises multiple challenges. these challenges comes from nature causes that hard to overcome like :

- **Fingerprints development :**

  For a newborn, fingerprints are not fully-developed which makes it hard to obtain a reliable image because the ridges are yet to be clear for measurement.

- **Skin changes :**

  The growth speed of newborns is really fast which makes changes in all parts of the human body including fingers. For that, fingerprints change over time which makes it difficult to obtain permanent data.

- **Birth fluids :**

  After birth, the baby gets covered with fluids such as vernix (a sticky material that surrounds the skin) which in some cases make it impossible to even capture the image of fingerprints.

3.2.2 Palm print :

After the 18th week of gestation, the papillary ridges on the palms and soles of the human fetus are fully formed [21]. As a result, in theory, it should be able to obtain dactyloscopic information on all babies. [21] Changed the technique used in the previous research to obtain a clearer image of the palms. ”After testing a variety of images for recognition purposes, we concluded that only images classified as “good” are useful to ensure the identity of the child before he/she leaves the hospital.” said [21]

Even after obtaining the images that ensure every child identity there some challenges that are complicated, we mention :

- **Difficulty of image acquisition :**

  To obtain “good” images from the palms of a newborn, it is a complicated process that makes the process longer and more costly.

- **Babies behaviour :**

  Babies tend to close their hands in their early age which makes the process more inconvenient for both the baby and the agent taking palmprint .

- **Sensitive skin :**

  The skin of babies are really sensitive, so the contact between baby’s palm and the sensor could damage the ridges leading to permanent change in the palmprint in the worst scenario.

We neglected iris, face recognition, hand geometry , ear shape ..etc for one main reason. the speed of growth causing a change in the features related to the stated ways of biometric recognition.

We suggested working in a way that avoids most of the challenges and with reasonable cost for its system and the most important factors are the accuracy and universality.

Footprint recognition showed excellent results within the adults, for that we are trying its application with the newborns, making a system for newborn recognition via footprint.

3.3 Identification of newborn through footprint :

There is a considerable amount of research in developing footprint as a biometric way of authentication, most of them are related to forensic. footprint is a major help in crime solving because it is a way to identify the culprit among the suspect and most criminals don't pay attention to it like fingerprints or DNA. So most studies are made for adult authentication. Apart from forensics, identifying corpses after a natural disaster field is in need for footprint development, using it provides alternative choices for identifying non-complete bodies (just lower half found).

It is a necessity to create a system that identifies newborns To avoid various problems such as mixing baby identities in the hospital and other problems related to governmental documents (ID card, passport..). After considering most biometric types, we chose footprint recognition.

Identification of children via footprints is the most used way in hospitals but it's not used in an automated way. Like we said before, the inc and the paper way is not precise and not practical due To multiple reasons such as the difficulty to acquire images from the paper.

According to previous researchers footprints recognition is the closest approach for identifying newborns, Where is the most important points that made us choose This method :

- **Unique patterns**:

  Footprints have distinct patterns that are unique to each individual just like fingerprints. The sole of the foot has an arch, whorl and loop that make identifying possible.

- **Ease of capture :**

  obtaining the footprint is relatively easy for newborns, by making an automated way we spare the babies the ink.

- **Permanence** :

  Footprint changes are minimum over the years compared to fingerprints.

- **Acceptability :**

  Footprints have a high acceptability among both people and governments.

From the image acquisition to the template comparison the image goes through multiple phases to be ready for usage as a biometric way for identification (or authentication) . here are the steps that the images of the footprint undergo from being captured to being stored at the database or compared to already stored data with explaining every phase:

1- Acquire image:

Acquiring images of the footprint is the only phase done by the hardware part of the system, the scanner is responsible for taking an image of the foot print which is the most critical phase. No other phase can operate with “bad” images. Therefore multiple researches based their focus on enhancing the efficiency of the scanner used in scanning footprints.

2- Pre-processing :

This phase is concerned with isolation of the footprint image from the originally obtained image by the scanner. As its name suggests this phase is preparing the image to be properly processed in the next stage by eliminating unnecessary parts like colors or non-part of the footprint from the image.Captured images undergo preprocessing. The coloured images are converted to gray scale and subsequently followed by binarization which involves assigning a threshold value.

The preprocessing stage is crucial. The capacity to normalize different rotations of a footprint is at the heart of pre-processing, and this procedure can vastly improve recognition accuracy. The obtained footprint (x, y) was then cut into L(x, y)t. The collected picture will then be turned to a standard angle to normalize the footprint, as shown in Eqs.1 using a rotation of θ degree for the foot[22].

$$L(x, y) = w(\alpha_L(x, y), \theta) \quad \textbf{(1)}$$

3- Feature extraction :

There are various approaches to extract features from the images of the footprint to use it for biometric authentication, every method is based on an equation. These methods are more efficient in specific areas (toe, sole…). Therefore, here are the base approaches and their corresponding equations:

- **<u>Ridge-based features</u> :**

  The word Ridges represent the raised lines found in footprints that produce distinct patterns. Ridge-based features examine the local direction and frequency of ridges in a footprint image. Gabor filters can be used to extract these features, as an example of methods that are specifically intended to capture ridge-like patterns.

Equation 2 is the equation used to describe the response of the Gabor filter at a specific pixel :

$$G(x, y) = exp\,(-\,(x'^{\wedge}2 + \gamma^{\wedge}2 * y'^{\wedge}2) \setminus (2 * \sigma^{\wedge}2)) * COS\,(2\pi * x' \setminus \lambda + \varphi) \qquad (2)$$

For further explaining here are what the characteristics on equation 2 represent :

- **x and y** : Coordinates of the pixel in the center of the gabor filter.
- **G(x,y)**: The filter's response at the pixel (x,y).
- **σ :** This controls the width of gabor's filter
- **γ :** Its role is to allow the ridge-like structure by controlling the ratio's aspect.
- **λ :** Determines the frequency of the ridges.
- **φ :** Phase offset.

- **Shape-based features :**

Eg. **Fourier descriptors** of footprint contour points can be constructed using the Discrete Fourier Transform (DFT). Equation 3 Below is the formula for calculating the Fourier descriptor :

$$F(k) = \sum(n=0 \text{ to } N-1)\ c(n) * exp(-2\pi * i * k * n / N) \qquad (3)$$

- F(k) : Represents the kth Fourier descriptor coefficient.
- c(n) : Represents the nth footprint contour point.
- N : is the total number of contour points in the footprint.

- **Statistical Features:**

Eg 1. **Mean** : The following equation eq 4, can be used to calculate the mean value the pixel intensities inside the footprint image:

$$Mean = (1 / N) \sum(i=1 \text{ to } N)\ I(i) \qquad (4)$$

The total number of pixels in the footprint image is denoted by N,and the intensity value of pixel i is represented by I(i).

Eg 2. **Local Binary Patterns (LBP):** LBP is a texture descriptor that tracks how frequently adjacent pixels move relative to one another within a local neighborhood. Eq 5 can be used to determine the LBP value:

$$\mathbf{LBP(x\_c, y\_c) = \sum(i=0 \text{ to } P-1)\ s(I(i) - I\_c) * 2^\wedge i} \quad (5)$$

Eq 5 can be detailed as follows :

- (x_c, y_c):bThe coordinates of the center pixel are .
- I_c stands for the central pixel's intensity value.
- The intensity value of the adjacent pixel at index is represented by I(i).
- P is the total number of adjacent pixels.
- The function called s(x) gives 1 if x is greater than 0 and 0 otherwise.

- **Structural Features:**

Eg. **Shape Context Descriptors**: A shape context descriptor captures how neighboring points are distributed around a reference point. You can use eq 6 to calculate how similar two shape contexts are to each other.

$$\mathbf{S= \sum(i=1 \text{ to } N) \sum(j=1 \text{ to } M)\ h(i, j) * \log(h(i, j) / (\sum(i=1 \text{ to } N) \sum(j=1 \text{ to } M)\ h(i, j)))} \quad (6)$$

where : **h(i, j)** represents the histogram value of the bin **(i, j)**.

- **Deep/ machine learning :**

Machines are said to have independently learned when they have the ability to adjust the structure, software, or data in response to a pre-defined input. Now that we've established what learning is for machines, we can define both machine learning and deep learning as modern techniques of image processing and data analysis with enormous potential, which greatly aided the field in growing incredibly popular among the IT community due to the doors they opened through their classification and detection capabilities. Deep learning, on the other hand, differs from machine learning in that it is a specialized subset that is a sophisticated and mathematically difficult evolution of machine learning [23].

Figure 3.3 explains the difference between machine learning and deep learning in the processing of biometrics.

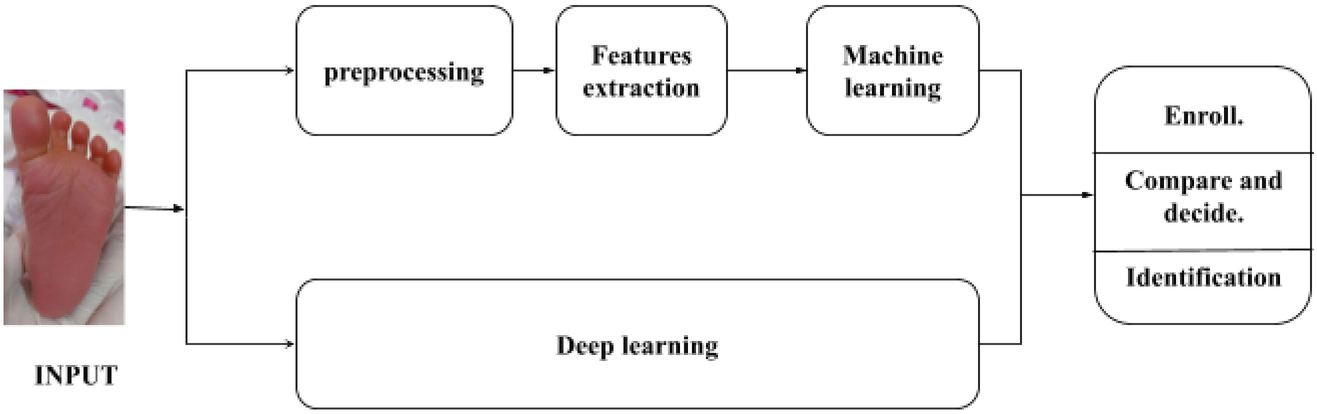

Figure 3.3 : Difference between deep and machine learning.

Biometric systems rely on machine learning techniques to extract significant features from biometric data and make informed decisions. These techniques encompass both traditional algorithms like support vector machines (SVM), k-nearest neighbors (KNN), and random forests, as well as more advanced deep learning algorithms such as convolutional neural networks (CNN), recurrent neural networks (RNN), and autoencoders.

The selection of a specific approach depends on several factors, including the complexity of the biometric data, the dataset size, the desired accuracy, and the specific requirements of the biometric system.

3.4 Convolutional Neural Networks (CNN) :

A Convolutional Neural Network (CNN) is a sort of deep learning architecture drawn from the visual systems of animals. The generalization ability of a CNN is substantially greater than that of other systems. It can identify highly abstracted features of objects and identify them more effectively, making it particularly strong in image processing. It is, nonetheless, useful in other disciplines, such as voice and natural language processing[24].

Convolutional neural networks (CNNs) have been used in image recognition since the 1980s, inspired by studies into the visual cortex of the brain. CNNs have achieved exceptional performance on a variety of demanding visual tasks in recent years, thanks to advancements in computer power and the quantity of available training data, which was previously a barrier to progress. Self-driving cars, automatic video classification systems, and other processing applications are examples of how CNNs are used in modern technology[25].

- **Types of layers in CNN:**

a) **Convolutional layer:**

Convolutional layers are the main components of CNN architectures. Convolution layers apply a filter or kernel to the incoming image to alter it. To build the feature map, the layer conducts dot product between the region of neurons in the input layer and the filters[26].

b) **Pooling Layer :**

CNNs frequently employ the pooling layer procedure after convolution layers to reduce dimension, also known as subsampling or downsampling. Pooling layer hyperparameters represent the filter size and strides. Pooling layers with filter size 2 and stride 2 are the most typically employed. Pooling layers are classified into two types: max pooling and average pooling, which take the maximum and average value, respectively. Max pooling is more commonly utilized than average pooling. The pooling layer has no parameters to learn. The concept behind max pooling is that a large number indicates the possibility of detecting a feature[26].

c) **Fully Connected layer :**

The CNN typically concludes with numerous completely connected layers after several convolution and pooling levels. The tensor at the output of these layers is turned into a vector, and then further neural network layers are added. As indicated in Fig. 3, the fully linked layers are typically the last few levels of the design. To prevent overfitting, the dropout [16] regularization approach can be performed in the fully connected layers. The architecture's last fully connected layer comprises the same number of output neurons as the number of classes to be recognized[26].

3.5 Proposed system :

This system consists in creating a biometric database for children in the minute of their birth by scanning their footprint by the device which is specially programmed to scan and process the image of the foot by an algorithm which distinguishes ridges and lines. The data recorded in the pc are connected by a network which uploads them automatically. The need for this system is essential to the evolution and development of the national database. After the application of this system we obtain practical solutions for very sensitive problems, such as the loss and abduction of children, the mix of babies at the maternity level and identification of corpses. Figure 3.4 explains how the system basically works.

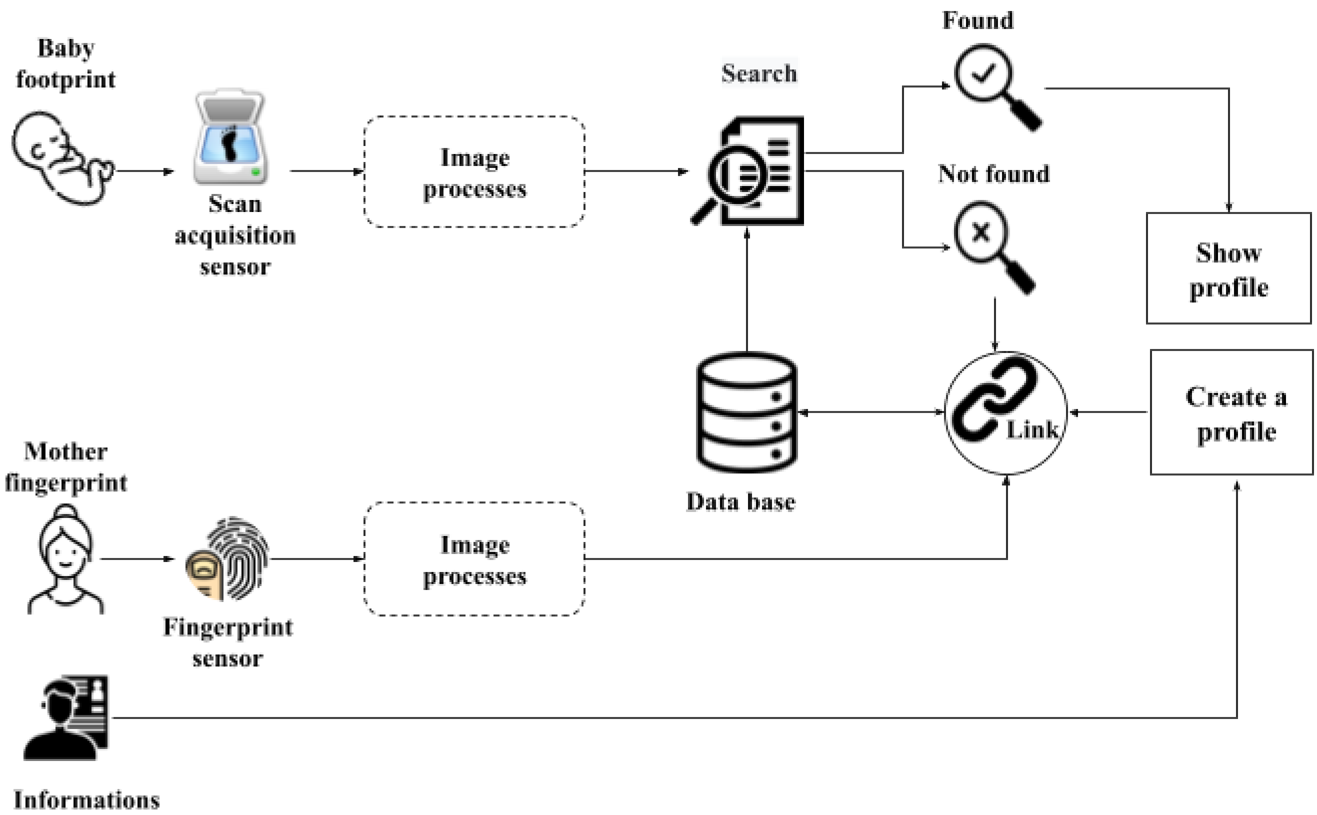

Figure 3.4 : Diagram of the system.

3.5.1 Image acquisition :

The proposed customized scanner aims to cater to the scanning needs of both fingerprints and footprints. It is designed to meet specific requirements, including dimensions that accommodate various foot sizes and the ability to capture high-definition details.

Additionally, the scanner should be designed to ensure that the baby's foot can be comfortably placed on the scanning surface, accommodating their specific foot size. The dimensions and ergonomics of the scanner should be suitable for capturing the required footprint areas without causing discomfort to the baby.

Furthermore, the scanner incorporates high-definition imaging technology to capture intricate details of both fingerprints and footprints. The resolution of the scanner is optimized to ensure that even the smallest features and patterns on the skin's surface are captured with exceptional clarity. This level of detail is crucial for accurate identification and analysis, enabling effective comparison and recognition algorithms to be applied.

3.5.2 Region of interest ROI :

This concerns just the footprint of the baby because the ROI of fingerprints is the whole captured area. In contrast , The footprint contains various places to be used as a way of authentication as stated in (2.5.3 characteristics of footprint) such as toeprint, the area under the big toe and the sole. Figure 3.5 shows the main ROIs in the footprint.

In our proposed system, we are primarily utilizing the sole region of the baby's footprint for identification purposes. There are two main reasons for focusing on the sole region: size and clearance.

Size : The sole of the foot generally provides a larger surface area compared to other regions of the footprint, such as the toe area. This larger area allows for capturing more distinctive features and patterns, increasing the accuracy and reliability of the identification process. By utilizing the entire sole region, we can obtain a comprehensive representation of the baby's unique footprint characteristics.

Clearance : The sole region is relatively less prone to smudging or interference during the scanning process compared to other areas like the toe print or the area under the big toe. When a baby's foot is placed on the scanning surface, the sole area comes in direct contact, minimizing the risk of accidental smudging or overlapping of patterns. This ensures that the captured image remains clear and unambiguous, leading to more accurate identification results

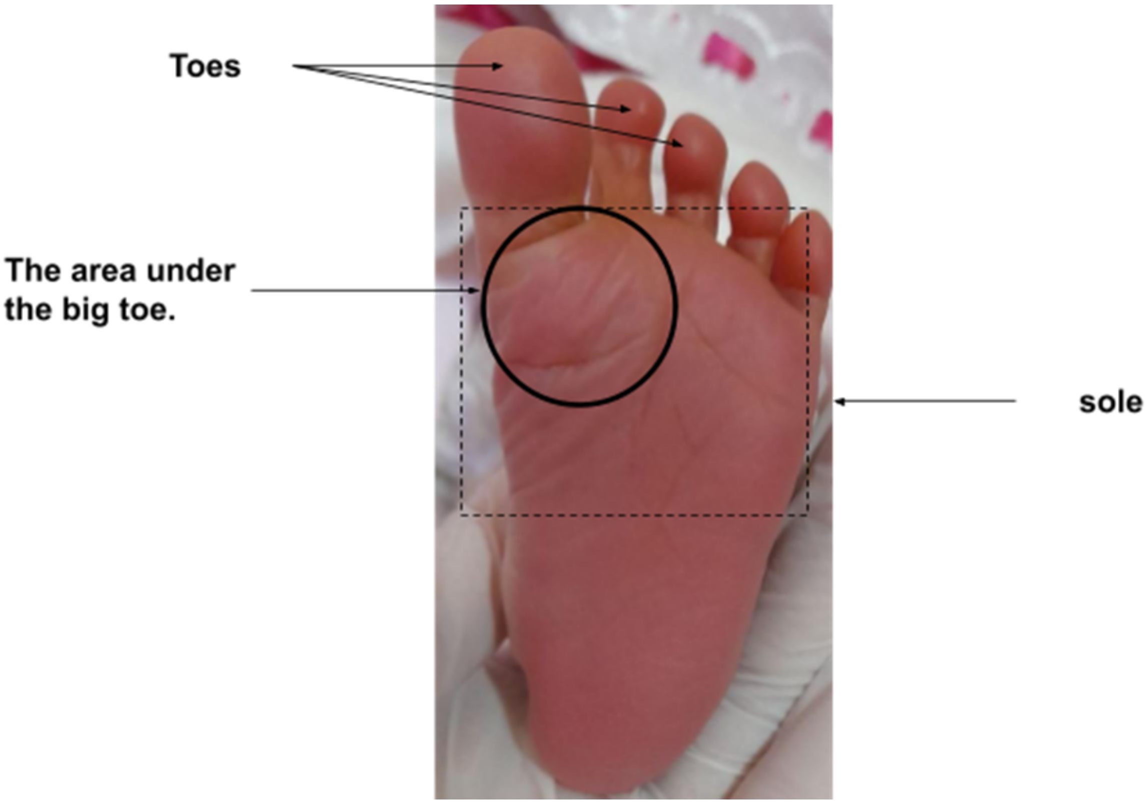

Figure 3.5 : Different area used for authentication in the foot.

The obtained image from the baby's foot undergoes two main changes in the preprocessing phase before the image process starts. The changes are isolating the foot shape from the unnecessary parts and putting it in grayscale. Figure 3.6 shows the two mentioned steps and the effect that every step makes on the image and the final result prepared for the next phase which is the ROI extraction. Figure 3.7 shows the final result of the ROI extraction and the area concerned with features extraction.

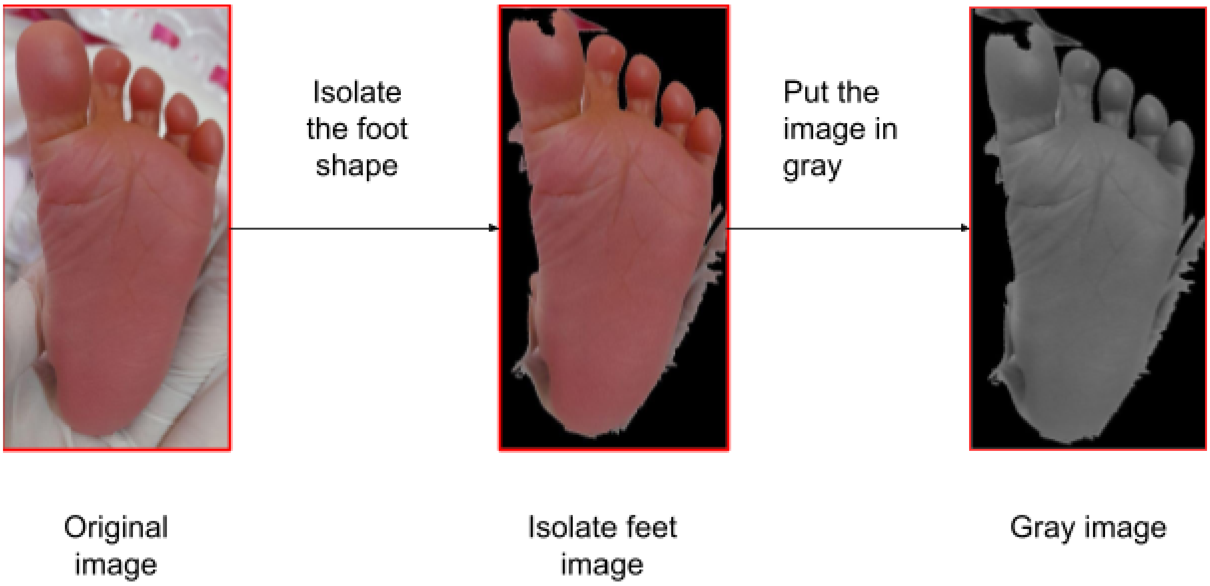

Figure 3.6 : The preprocess of the image.

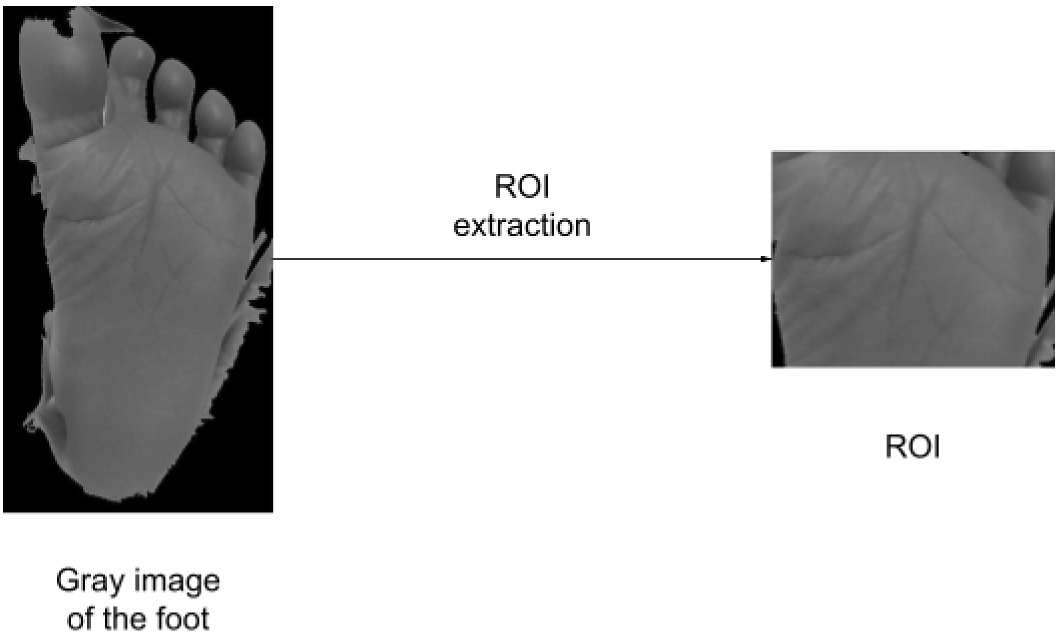

Figure 3.7 : ROI extraction.

3.5.3 Features extraction :

Feature extraction from the sole of a footprint involves the process of identifying and capturing the distinctive characteristics present in the sole region, which can be used for identification and authentication purposes. Here are some key aspects of feature extraction from the sole of a footprint:

- **Dermal Ridges:**

  The sole of a foot contains unique patterns of lines and ridges known as dermal ridges. These ridges are formed by the papillary ridges on the skin's surface and are highly individualistic. Feature extraction algorithms analyze the arrangement, shape, and connectivity of these ridges to create a unique representation of the foot's sole.

- **Ridge Count:**

  Ridge count refers to the number of ridges present within a specific area of the sole. Feature extraction techniques calculate the ridge count in various regions of the sole, such as the heel, arch, and ball. The ridge count can be used as a discriminative feature to distinguish between different footprints.

- **Ridge Shape and Orientation:**

  Another important aspect is the shape and orientation of the ridges within the sole region. Feature extraction algorithms analyze the curvature, direction, and continuity of the ridges to create a distinctive representation. The unique patterns formed by these ridge features provide valuable information for identification.

- **Ridge Characteristics:**

  Various characteristics of the ridges, such as ridge endings, bifurcations, enclosures, and crossovers, are considered during feature extraction. These characteristics help in creating a detailed and discriminative representation of the sole pattern.

- **Texture Analysis:**

  Texture features are extracted to capture the finer details within the sole region. This involves analyzing the texture variations, such as smooth regions, rough patches, or specific texture patterns, present in the foot's sole.

- **Spatial Relationships**: Feature extraction also considers the spatial relationships between different ridge features. This includes analyzing the distances, angles, and connectivity between ridge endings, bifurcations, or other characteristic points within the sole pattern.

The feature extraction process may employ various techniques such as image processing, pattern recognition algorithms, and machine learning methods. These techniques aim to extract the most relevant and discriminative features from the sole region, which can be used for comparison, identification, and authentication purposes.

It's worth noting that feature extraction algorithms may vary depending on the specific system or application requirements. Different algorithms may prioritize certain features or use additional techniques to enhance the accuracy and robustness of the extracted feature**s.**

3.5.4 Enrollment :

Giving birth to a child is a very hard work to do that gives the body of the mother and the mind a very hard shock, for tat we have to be our system a helping hand that assure the safety of her child and it won't be mixed and the operation to register should not be an inconvenience for either the mother or medical staff.

The order and the time of the enrollment is very important for the purpose of the system and its performance. The baby's footprint should be the first input and then right after comes the fingerprint of the mother. The fingerprint of the mother is like her confirmation that the previous footprint is hers. Figure 3.8 shows the order of the enrollment phase.

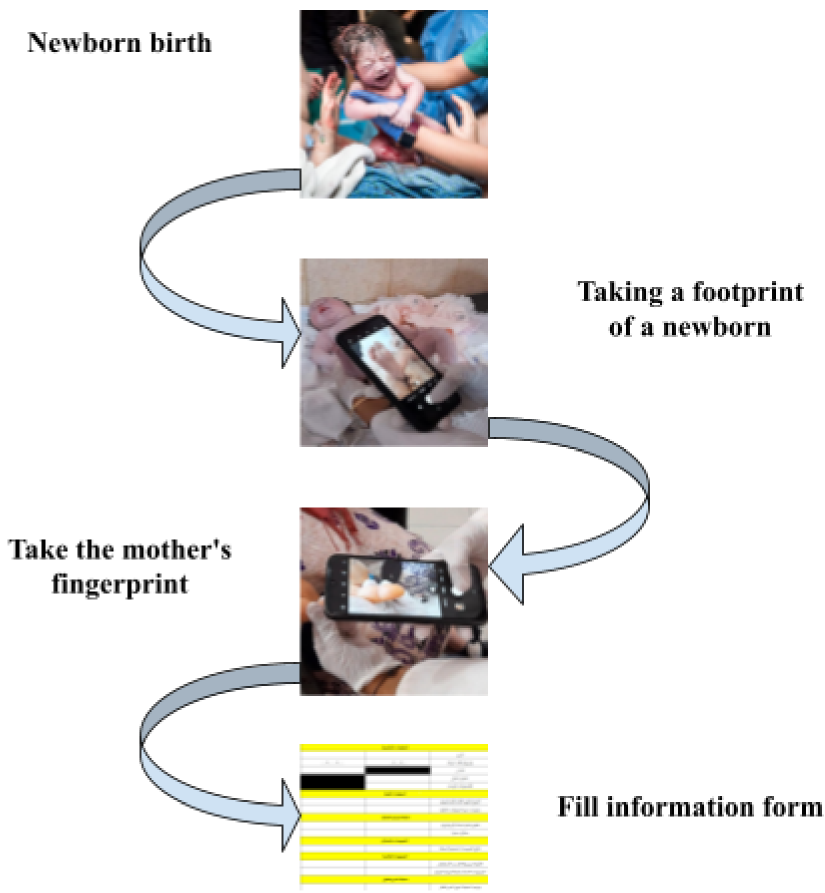

Figure 3.8: The order of the enrollment phase

3.5.5 Filling up information:

Filling up information is the last step and it is the most important step in the old protocole, but we minimized it. After scanning both fingerprint and footprint an excel type file opens, the file is modified (not totally empty) with empty cells that need to be filled with the needed information. Figure 3.9 shows an example of the excel file

المعلومات الشخصية		
	الام	المولود
الاسم		
تواريخ ومكان الميلاد	...../......./......	......../........./........
الجنس		
العنوان الحالي		
أرقام هواتف التواصل		
المعلومات الطبية		
التاريخ الطبي الكامل للأم والمولود		
معلومات حول التشوهات الخلقية		
الحالة الصحية الحالية		
التقييم العام لصحة الأم والمولود		
مشاكل صحية		
الفحوصات والتحاليل		
نتائج الفحوصات المخبرية السابقة		
التوجيهات العلاجية		
الأدوية الموصوفة لكل من الأم والطفل		
التوجيهات الخاصة بالرعاية اليومية للمولود		
متابعة النمو والتطور		
مواعيد المتابعة الدورية لنمو الطفل		

Figure 3.9 : An example of the attached excel file.

3.5.6 Verification:

In the process of the system, the cases where the verification needed are when the baby leaves, mother claims that the baby is/is not hers, names mixed.

Cases	Verification
Case 1	Putting the newborn's footprint, and the mother's medical file appears
Case 2	The footprint of the newborn is placed, and the fingerprint of the mother is placed. If there is agreement between them, the sign of approval appears, and vice versa.

Table 2: Different cases that need a verification

- **Case 1 :** The baby leaves the hospital with/without his mother,or conflict between mothers or a claim from the mother that the baby is/ is not hers.
- **Case 2:** The medical staff mixes the names of unconvinced mothers from case 1.

3.5.7 What does the system need? :

The goal is to make a practical system that suits the following conditions :

- **Accuracy :**

  This system provides a unique service that does not tolerate any mistake at all, for that we need to put the performance of the system at a high degree of accuracy and deliver our service without mistakes.

- **Easy to use :**

  We intend to install the system in the birth clinics (private or public), which is a sensitive place where the time is an important factor. The people operating the system are the medical agents not technicians so the system must be very easy to use and does not waste time.

- **Low cost :**

  For the system to be widely used, we have to manufacture it with reasonable cost . Therefore, we need a study for the cost of every part of the system.

Chapter 04:

Results and discussion.

Chapter 04: Results and discussion.

4.1 Introduction:

This chapter is to discuss the experiment that we did and their results. We will discuss the three main parts of our system and the steps of every part. We created a database for baby's footprint to train our code that process and classify the images and then test it with different dataset and the users. After that we go to the second step to adjust the first code to ask for another input along with the footprint which is fingerprint. The goal is to store them in one folder every time we enter inputs (fingerprint and footprint) .the last step is to create a file in the same mentioned folder (e.g. an excel file) that contains the users identification.

As stated before, the system has three inputs which are baby's footprint, fingerprint of the mother and the identification of the mother (Name and medical record..etc).

4.2 Data description:

Our system needed two set of (biometric) data:

4.2.1 Footprint data:

The data of the footprint was acquired by taking pictures in the hospital of mother and child "Omar Boukhris"- Ouargla. The image was taken by "", after that the image went through a preprocessing. This phase was mentioned in (figure 3.6) the result of that preprocessing undergo another step which is the ROI extractions shown in figure 3.7. That data will be put in a specific order for the main code to operate.

Table 3: Data description.

Sex	Number of babies	Right foot	Left foot	Total
Male	12	3	3	72
Female	18	3	3	108
Total	30	90	90	180

Note: please note that this data is acceptable out of the total that we obtained which is 500 images (50 baby 10 each foot), we eliminate the rest due to errors in the capturing.

4.2.2 Fingerprint data:

Fingerprint data is more common, so the data acquiring was not hard to obtain as the footprint data which was way less common. We made a dataset for fingerprints with the same number of the footprint available.

As for the personal information we created a list of random names and other information just to complete and test this system and its efficiency.

4.3 Work environment:

4.3.1 Physical environment:

- **Laptop** : The characteristics were as follows :
  - Processor: Intel(R) Core(TM) i5-5300U CPU @ 2.30GHz 2.29 GHz.
  - Memory : RAM 8,00 Go.
  - System type : of System d'exploitation 64 bits, processeur x64
- **Smartphone (as a camera)** :
  - 48 MP, f/2.0,(wide),1/2.2",0.8µ,PDAF

4.3.2 Software environment:

Utilizing Google Colab as our system has a number of benefits. First off, it offers a productive setting for creating and running Python programs. In particular for jobs involving machine learning or sizable datasets, Colab offers powerful hardware resources, like GPUs and TPUs, which can greatly speed up computations.

Additionally, Python and its dependencies no longer require local installation and configuration thanks to Google Colab. It makes it simple to use well-known Python libraries and frameworks like NumPy, Pandas, and TensorFlow in your code because they are preloaded on the system.

You can also simply import and export data from a variety of sources thanks to Google Colab's connectivity with other Google services like Google Drive (that we used as our data and output holder. Our work will always be available and safely kept if you save and load notebooks directly from your Google Drive.

4.4 Experiments and Results:

The part concerning the footprint is the essential part of the experiment because this is the part that needs testing and improving. Fingerprint processing and classification is developed to an efficient degree therefore we don't need to work on it. As for the last part, we already created a code that does the last mission (mentioned in 3.4.6) in the system.

In order to compare our results we chose the following criteria:

- **For footprint:**
    - **Equal Error Rate (EER):** The point when the FAR is equal to the FRR. The theoretical distribution of probability ratios of genuine users and impostor
    - **Rank One Recognition (ROR)**: The percentage of individuals who are recognized by a biometric system based on a rank variable known as ROR. The ROR rate is determined when rank is equal to one.
- **For fingerprint :**
    - **accuracy.**

4.4.1 Footprint experiment :

For the sake of exploring more than one method of processing and classifying images of the footprint we work in two approaches as follows :

- **Texture extraction method:**

    In this method we train our model to extract the texture from the footprint using Gabor filters and image processing techniques such as Low-Pass Gaussian Filtering,Histogram Equalization,Thresholding..etc

    Figure 4.1 shows the process the images undergo after using the Gabor filter.

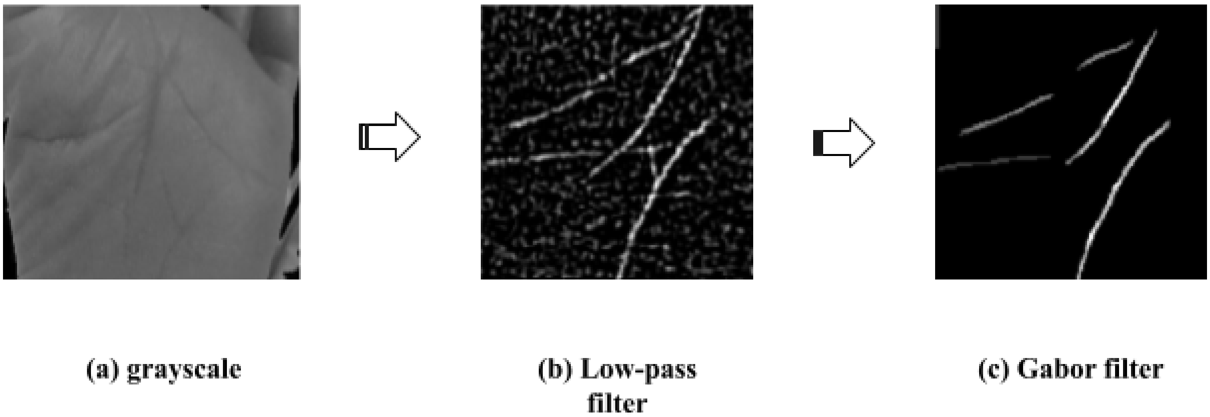

Figure 4.1 The process the images undergo after using the Gabor filter.

The foot image is initially transformed to grayscale to represent intensity levels in the image processing pipeline outlined. The image is then smoothed and high-frequency noise is reduced using a low-pass filter. Following that, a Gabor filter is used to extract texture and frequency information from the image, amplifying specific patterns and characteristics. The generated images (a), (b), and (c) correspondingly exhibit the grayscale foot image, the image after low-pass filtering, and the image after Gabor filtering. Overall, these procedures help to extract significant image qualities including intensity, smoothness, and texture, which are useful for further analysis or applications in foot image processing.

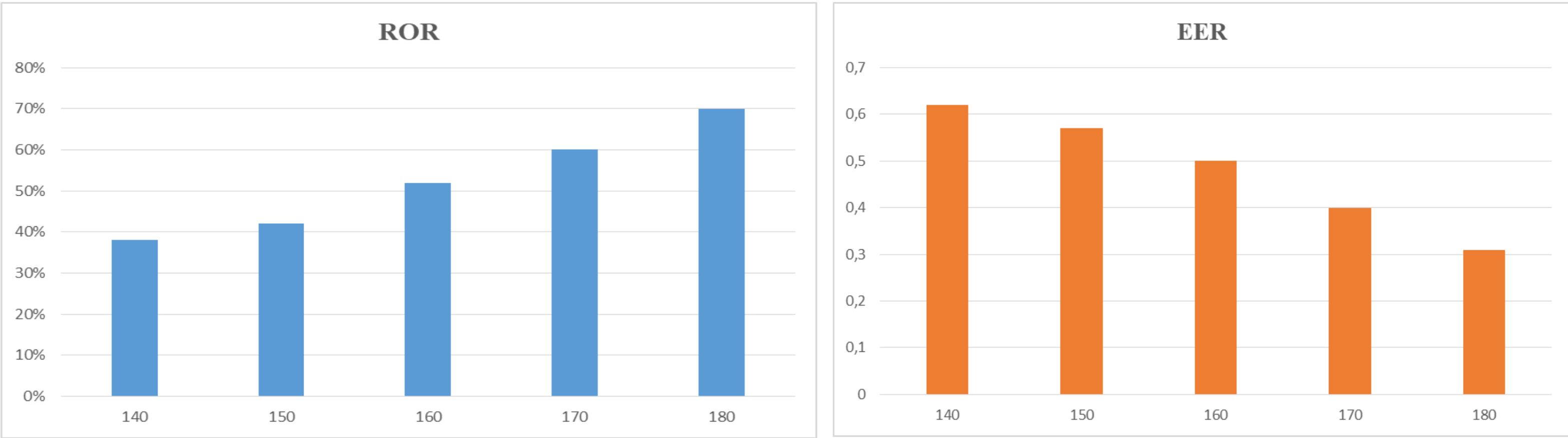

Figure 4.2 : Histogram of the variation of EER and ROR based on the number of images

- **CNN method :**

We tried to use the CNN approach for our footprint recognition system. However, we encountered difficulties owing to the small size of your training database. To properly learn and generalize patterns from input data, a CNN model requires a big and diverse dataset. In your scenario, the model will struggle to grasp the underlying patterns and variations contained in footprints due to a tiny database, resulting in inferior performance and illogical outputs.

4.4.2 Fingerprint experiment :

Our fingerprint recognition system has two modes of operation. The first and most basic mode is known as pre-verification. The first in this mode is based on various fingerprint qualities, the image is classed as either real or false. If the input image is real, the system sends it to the identification phase; if the image is fraudulent, the system pauses the process of granting access to a specific person. Security will be strengthened by using the preverification phase system Because it confirms that the image is not a hoax.

During the identification step, the subject id and finger number are anticipated, and fingerprint matching is done using precise level minutiae characteristics. And if the prediction probability is more than 91% and the system finds the best match with the stored template, the system will provide access to that specific user.

- **First phase results (preverification):**

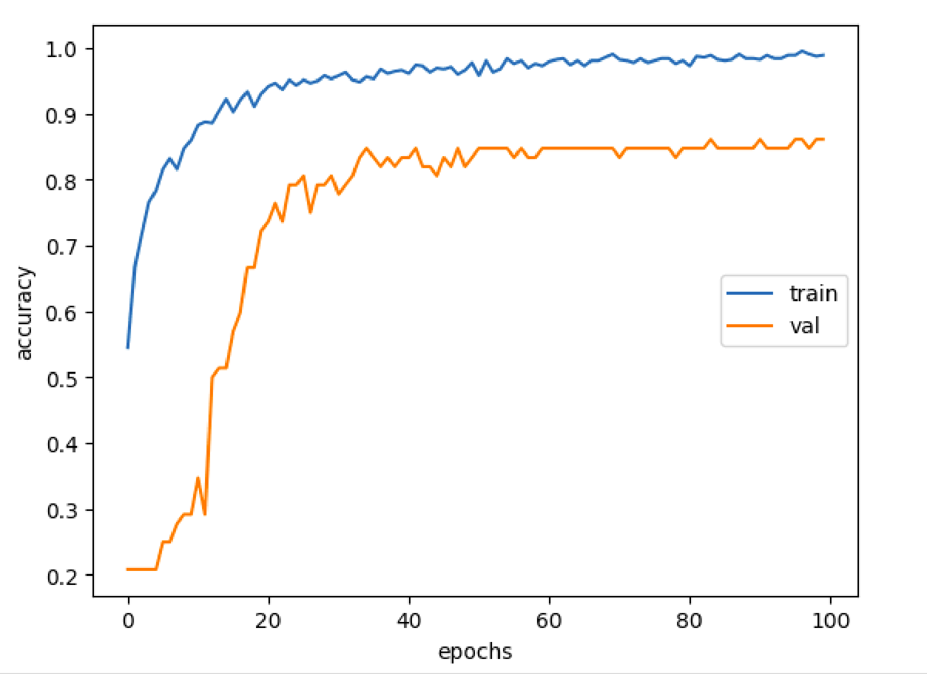

Figure 4.3 : Pre-verification module performance.

Comment :

The accuracy versus epochs graph is an important visualization for analyzing the performance of a machine learning model. In this situation, it is seen that the training accuracy (97%) is higher than the validation accuracy (87%).

A high training accuracy suggests that the model learned effectively from the training data and can predict accurately on previous data. However, a significant disparity in training and validation accuracies suggests a potential overfitting problem. Overfitting occurs when a model gets overly specialized to the training data and is unable to generalize adequately to new data.

- **Second phase results (Matching Model) :**

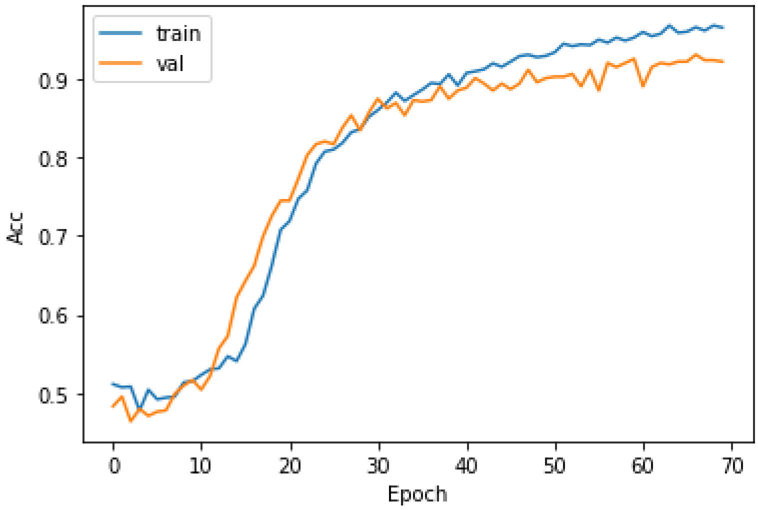

Figure 4.4 : Matching model performance.

Comment :

The accuracy versus epoch graph reveals some intriguing trends. Initially, training accuracy rises quickly and reaches a high of 97%. This implies that the model is learning effectively from the training data and improving its predicting abilities. The validation accuracy, on the other hand, begins at a lower number, probably due to the model's initial lack of generalization to unknown data. However, as training goes, validation accuracy gradually improves and stabilizes in the 80s. This implies that the model is learning and improving on unseen data, but it is not achieving the same degree of accuracy as on training data.

4.5 Conclusion :

The pre-verification model graph indicates a considerable disparity between training accuracy, which approaches 97%, and validation accuracy, which barely reaches the low 80s. This signals a potential overfitting problem, in which the model performs well on the training data but struggles to generalize to new, unknown data.

The graph for the matching mode, on the other hand, indicates a more balanced performance. Although training accuracy is initially slightly higher, validation accuracy eventually increases and stabilizes around 91%. This shows that the model is learning and generalizing well, as evidenced by its relatively high accuracy on previously unseen data.

To summarize, the pre-verification model requires additional attention in order to solve overfitting and increase generalization capabilities. The matching mode model, on the other hand, shows more promising findings, with a balanced performance between training and validation accuracy.

Chapter 05:
General conclusion

In conclusion, implementing the newborn footprint recognition system can provide significant benefits in the health sector by enabling the creation of comprehensive medical histories for individuals and delivering accurate information at a much faster rate than the current rate of information retrieval. As a result, healthcare statistics become more accurate, and data analysis becomes easier.
our system can contribute a lot in health sector digitisation especially in :

- **Creating a medical history :** By incorporating the neonatal footprint identification technology into the health sector, footprints can serve as a unique biometric identifier connected to an individual's medical records. Because footprints are collected at birth and linked to a person's identification, a digital medical history may be produced and maintained for the rest of their lives. Immunizations, allergies, medical procedures, and continuing health issues can all be included in this history. Access to this entire medical history enables healthcare practitioners to make more informed decisions, improve treatment outcomes, and ensure continuity of care.
- **Improved healthcare statistics and data analysis :** The incorporation of the neonatal footprint recognition technology simplifies data gathering and increases the accuracy of healthcare statistics. Healthcare facilities can collect reliable data on patient demographics, medical problems, treatment outcomes, and epidemiological trends by precisely identifying and matching individuals' footprints. This information can then be used for in-depth statistical analysis, research, and resource allocation. The system's accurate and up-to-date information improves the quality of healthcare services and adds to evidence-based decision-making.

The newborn footprint identification system's significance goes beyond addressing healthcare digitization concerns. It also addresses critical and dangerous issues in our society, improving safety and well-being. Let's take a closer look at some of these issues.

It is critical to focus on training the model for the next phase of your work on the footprint identification system, which comprises two key components: designing an accurate and easy-to-use sensor and creating a vast and diverse dataset that represents different sections of the country.
Our future work will focus on the following point :

- **Sensor development**: In order to properly capture footprints, a sensor that is both accurate and user-friendly must be designed and developed. The sensor should be able to capture high-resolution photos of precise footprints. It should also be simple to use, allowing healthcare providers to easily take footprint pictures from babies. The sensor's design should prioritize simplicity, reliability, and non-intrusiveness to ensure a smooth data acquisition process.
- **Create a comprehensive and detailed dataset:** Creating a comprehensive and detailed dataset is critical for training a robust footprint recognition algorithm. Footprints from diverse locations or portions of the country should be included in the

collection to account for demographic differences such as foot size, shape, and texture. Data collection from various races, geographical places, and cultural backgrounds can aid in the creation of a broad and representative dataset. To ensure the model's versatility and usefulness in real-world circumstances, it is critical to integrate footprints from neonates with various conditions, such as premature births or medical issues.

We may substantially improve the newborn footprint recognition system by focusing on the construction of an accurate and simple-to-use sensor as well as the creation of a vast and diverse dataset representing different parts of the country. Improving the dataset by including footprints from varied demographics, geographical areas, and medical situations guarantees that newborn footprints are accurately represented. This, together with proper labeling and metadata, will make training a robust and efficient model easier. Concurrently, the development of a user-friendly sensor capable of capturing high-resolution footprint photos will speed up the data acquisition process.

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