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Survey of Fingerprint Technology, Challenges and Orientation

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Abstract

A fingerprint is created by the ridges on a person's finger that create friction and create an impression. A crucial forensic science process is the partial recovery of fingerprints from a crime scene. Because of the moisture and oil on a finger, fingerprints may be detected on glass and metal. Fingerprints may be imprinted on paper by applying an ink or other substance to the ridges of the skin friction, such as using an ink pen. Both the finger's lower joint and its final joint pad imprints are often recorded by fingerprint cards. Human fingerprints are good long-term identifiers of human identity because they are detailed, nearly unique, difficult to manipulate, and durable. People who don't want their names revealed, as well as those who are disabled or dead, may be recognized via the usage of these devices if a natural disaster occurs.

Keywords: Fingerprint Technology, Fingerprint Perspectives, Orientation with Fingerprints.

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1. Introduction

When a human finger touches a surface, the friction ridges on the finger create a fingerprint. Fingerprint matching is a widely used and dependable biometric process. There are a number of factors that may be taken into consideration when matching fingerprints.

Forensic fingerprint analysis has been used to catch criminals for more than a century. The procedure begins with a "latent" or "deposited" print. A crime scene's latent print may be visually matched to a suspect's fingerprint provided it is sufficiently detailed [2, 3]. When analyzing a print, experts look at aspects including its general shape and size, as well as ridge depth and length. Afterwards, the analyst applies his or her expertise to establish whether or not the prints are really a match. Following confirmation by another expert, it is determined whether or not this approach was used by a suspect to place their latent print [4, 5].

Figure 1: Ridges and Curves in Fingerprint.

Generally, it is assumed that a latent print matching the suspect's fingerprints was placed there by the suspect since no two fingerprints are ever exactly identical. As far as I know, there are no studies or analyses that support this notion. So in other words, scientific data does not support the assumption that each person's fingerprint is unique [6, 7, 8]. [9, 10, 11] In fact, a high-profile case

of innocence demonstrates this notion to be false. As a result of his fingerprints being found at the 2004 Madrid train bombing site, an Oregon attorney was arrested as a material witness

The assaults left 191 people dead and hundreds more wounded. An Algerian national called Ouhnane Daoud and his accomplices were found guilty after a 17-day inquiry by Spanish authorities. Due to the event, the FBI issued an apology and conducted a comprehensive review of their fingerprint processing procedures to make reparations [12, 13, 14].

Figure 2: Fingerprint Arch.

Subjectivity is an issue in fingerprint analysis as in other forensic science areas. Instead of using tried-and-true scientific procedures, the approach mainly depends on the analyst's subjective judgments. The approach is intentionally kept subjective in order to allow the examiner to judge the quality of each ridge in the specific prints being investigated. However, this may lead to inaccurate results that are difficult to replicate. It is the examiner's choice, not the reliability of the features that decides which characteristics are employed in a specific fingerprint analysis [15, 16,17].

In spite of their subjective character, fingerprint analysts typically speak about absolute certainty. The findings are occasionally misrepresented to jurors as scientific certainty with devastating

effects because of the subjective character of the testing procedure, the absence of criteria used to evaluate if a match or exclusion exists, and the overall lack of validity. A claim by the National Academy of Sciences that fingerprint analysis is error-free is simply false, according to the Academy. To put it another way, researchers may begin to restrict their confidence in figuring out whether a print is linked to a certain person. [18, 19, 20].

As a result of one or more friction ridge skin ridge units lifting a person's finger or toe or palm or sole, friction ridge skin is referred to as a friction ridge.

They're known as "epidermal ridges" because the dermal papillae of the epidermis come into direct touch with the interpapillary (rete) pegs of the epidermis. When a fingertip brushes against an uneven surface, vibrations may be amplified and conveyed more efficiently to sensory neurons via these epidermal ridges, which are implicated in fine texture perception. They may also help with surface contact when it is wet, as well as give traction on rough terrain [21, 22, 23].

Figure 3: Fingerprint Loop.

Figure 4: Fingerprint Whorl.

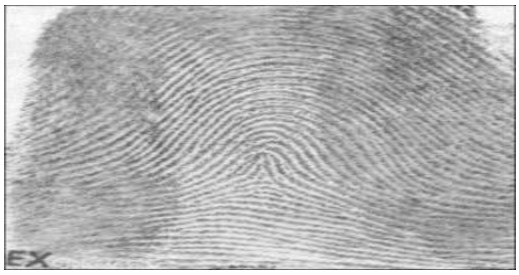

Figure 5: Tented Arch.

Systems for categorization

- The arch of a finger print
- Loops of fingerprints
- In the form of a whorl of fingerprints

2. The arch of a fingerprint:

Large fingerprint collections employed manual filing techniques prior to the introduction of computers [24].

A fingerprint classification system, for example, makes it possible to compare a single fingerprint to a large collection of fingerprints by classifying them based on several characteristics. As a result, a portion of the fingerprints in an existing database may be used to compare query fingerprints. The ridge patterns of many or all fingers were utilized as a basis for early classification methods. Paper records may be stored and retrieved using friction ridge patterns alone. Using the pattern class of each finger, a number key was created to help in the search of a file system. Fingerprint categorization systems such as the Roscher, Juan Vucetich, and Henry Classification Systems are all examples of this. The Roscher System, developed in Germany, has been used in both that country and Japan. Vucetich was initially brought to South America in Argentina, where it was first used. The Henry Classification System, developed in India, is widely used in English-speaking countries [25,26].

Loop, whorl, and arch are the three most prevalent fingerprint patterns in the Henry Classification System, accounting for 60% to 66% of all fingerprints.

The direction the loop's tail points in regard to the hand is used by a number of additional classification techniques to separate patterns into tented arches and radial loops as well. A loop begins on the pinky-side of the finger, which is nearer to the ulna (the lower arm bone) than any other part of the finger. [27,28, 29]. Circular patterns start on the thumb side, which is nearer to the radius. Sub-groups of whorls include plain whorls, accidental whorls, double loop whorls, peacock's eye whorls, composite whorls, and central pocket whorls.

In order to identify ridge endpoints and ridge bifurcations in fingerprint images, a feature extractor is used. If the ridges in the input fingerprint image can be accurately located, the minutiae extraction of single points in a thinned ridge map is quite easy. Of fact, a perfectly accurate ridge map isn't always possible in practise. For the current minutiae extraction methods, it is critical to have high-quality fingerprint pictures as an initial input. For a number of reasons, fingerprint pictures may not always show well visible ridge patterns (abnormal formations of epidermal ridges of fingerprints, postnatal markings, occupational marks [25] issues with acquisition equipment, etc.).

The precision of the minutiae extraction approach is critical to the effectiveness of a fingerprint-based identity verification system. In essence, it's made up of three parts: Orientation estimation, ridge extraction, and minutiae extraction are all part of the procedure.

When looking at a fingerprint photo, you may be able to tell the directionality of the ridges by examining the image's orientation field. In the process of analyzing fingerprint images, it's an essential step. Several methods exist for estimating the orientation field of fingerprint images. Each block is given an orientation suggestive of ridges in the fingerprint picture based on a study of grayscale gradients in the block, which is typical for fingerprint images split into many non-overlapping blocks (e.g. 32 X 32 pixels). There are a number of ways to pick the block orientation, such as averaging, voting, or optimization.

Images of fingerprints must be divided into many regions in order to adequately depict the finger (foreground). The easiest way to separate the foreground from the background is to use global or adaptive thresholding. Ratha has created remarkable and precise segmentation of fingerprint patterns utilizing changes in grey level variance along and across a fingerprint's ridge. Variance calculation typically uses a block size of 1-2 inter-ridge distances.

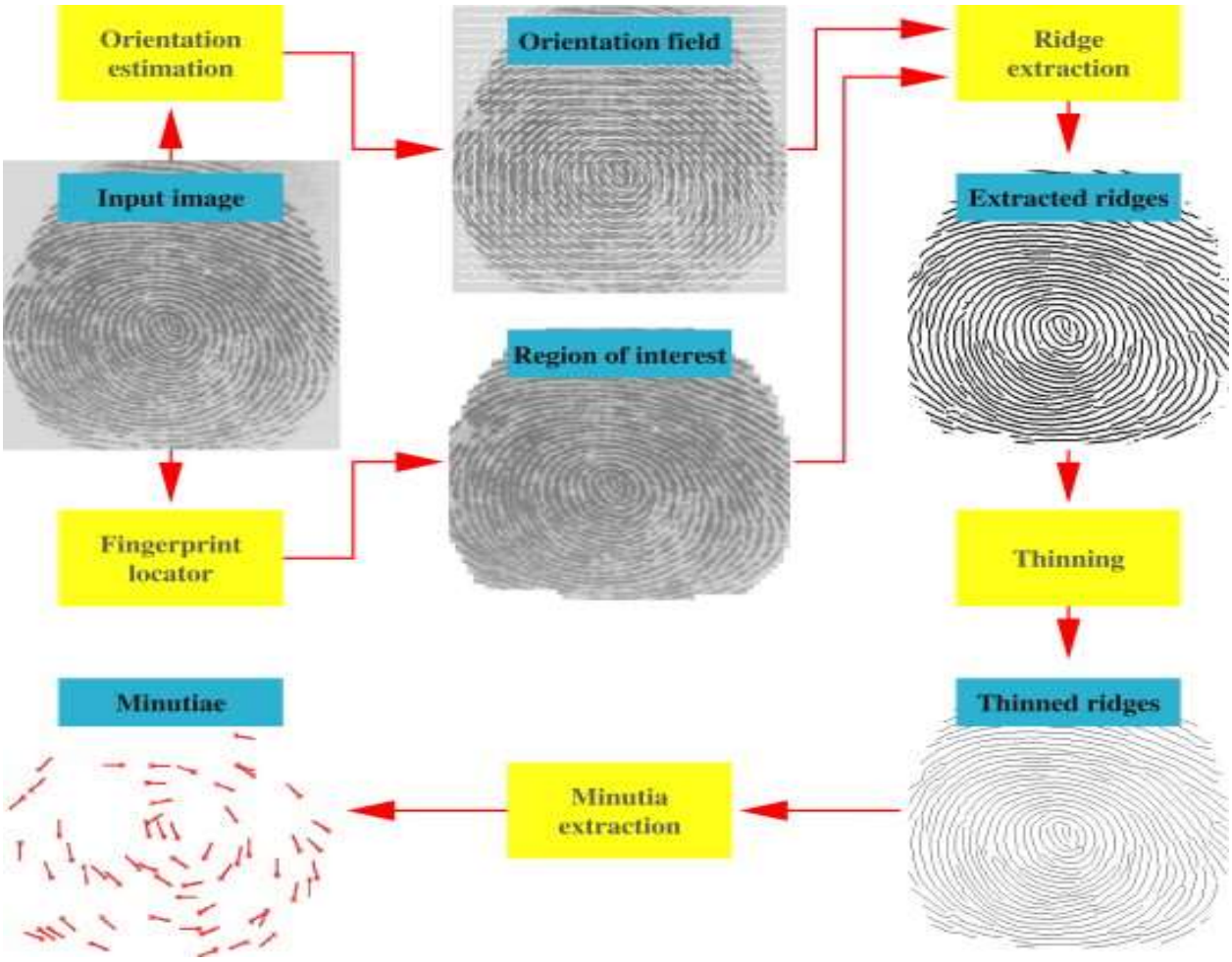

Figure 6: Extraction Patterns.

Ridge detection may be done using either a simple or an adaptive thresholding approach, depending on the application. These approaches may not work if the picture is too noisy or lacks contrast. When examining fingerprint photos, it's worth noting how local orientation correlates with the peaking of grey level values on ridges [30, 31, 40]. This feature may be used to identify pixels as ridged pixels. The retrieved ridges may be thinned or cleaned using standard thinning and linked component procedures [32,33].

The ridge bifurcations and ridge endings are named after the thinning ridge map is complete, and the ridge pixels with three ridge pixel neighbors and one ridge pixel neighbor, respectively, are recognized. Image processing errors and fingerprint picture noise have rendered all of the details detected inaccurate.

Many heuristics are used in the post-processing step in order to recover the actual minutiae from the retrieved minutiae. A lot of minute features in a limited region may, for example, indicate a lot of noise if there are many of them. Erroneous minutia may be produced by a ridge break caused by poor contrast or a cut on the finger, as well as by ridge terminals that are excessively close and antiparallel to one another. When two bifurcations are particularly close to one another and share a comparable short ridge, dirt or image processing flaws might make the bridging of neighboring ridges seem as superfluous minutia.

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It is usual to use simple or adaptive thresholding to identify ridges in data. These techniques may fail if the picture is too noisy or has a weak contrast. Consider how the grey level values on fingerprint ridges tend to peak in the same direction as their local orientation when looking at fingerprint photographs. This feature may be used to identify pixels as ridged pixels. 'In order to clean or thin the extracted ridges, the standard thinning and connected component procedures may be applied.

A thinned-out ridge map identifies ridge bifurcations and ends by looking for pixels with three or more adjacent neighbors. Image processing errors and fingerprint picture noise have rendered all of the details detected inaccurate.

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Acquiring high-quality fingerprint images for use in an automated fingerprint identification system is considered as the most critical step in determining overall system performance. For the most part, fingerprint scanners still depend on the physical differences between fingerprints to establish who an individual belongs to.

Optical and solid-state fingerprint scanners are the two most prevalent technology families on display. With an optical, ultrasound, capacitive, or thermal fingerprint sensor (see Fingerprint sensors), rolling or touching the detecting area with your finger is necessary to acquire a picture of your fingerprint's valleys and ridges. When a finger is forced against anything, the supple skin of the finger bends. An irregular 3D object projected onto a 2D flat surface may distort a fingerprint

image, as can the skin condition of an individual user. These defects have resulted in an image with a wide range of blemishes that are variable and erratic. As a consequence, each collection yields different imaging findings that are difficult to anticipate. Because the fingerprint's representation changes every time a finger is placed on the sensor plate, the system slows down, making fingerprint matching more difficult, and eventually inhibiting its widespread adoption [29].

These difficulties were addressed in 2010 by the development of non-contact or touchless 3D fingerprint scanners. The analogue technique of pressing or rolling the finger is digitally digitized by 3D fingerprint scanners. The spacing between close dots may be used to model the fingerprint in order to collect all important information.

Due of the skin's capacity to renew and other environmental effects, fingerprinting a person is more challenging. After a person dies, their skin gets drier and colder. It is impossible to get fingerprints from a deceased person's body since only a coroner or medical examiner has the authority to inspect it. The fingerprints of the dead may be obtained during autopsies. Latent fingerprints on fabrics, notably on the insides of discarded offenders' gloves, were discovered in the 1930s by American criminal investigators.

Law enforcement agencies throughout the globe have been using fingerprint identification technology to identify criminal suspects and victims of crime since the late eighteenth century. The fingerprinting process is based on a simple principle. Papillary ridges on the palmar surface of the hand and foot are unique to each individual and do not change over time. Because of this, even identical twins do not have the same fingerprint patterns. Photographing latent fingerprints may be a challenging process, depending on the kind of surface they were put on. You'll need a "developer," a powder or chemical solution, to get a good image of the fingerprint's ridge patterns and the backdrop.

The presence of organic compounds or inorganic salts, as well as the amount of water deposited, affects the effectiveness of developing agents. Accumulated material from the sebaceous glands predominantly on the forehead, together with eccrine gland secretions in the

fingers and palms, is what makes up the majority of fingerprints. Touching one's face or hair is a common human behavior that leads to contamination. It is made up of water, amino acids, and chlorides, as well as a fatty component that is made up of various fatty acids and triglycerides. Amino acids and urea are examples of reactive chemical molecules that are notoriously difficult to detect.

Simple powders or chemicals left at the scene of a crime may be used to find fingerprints. It is possible to use modern chemical techniques in a specialized laboratory for testing and analysis of objects retrieved from a crime scene. These more advanced methods have made it possible for forensic labs to identify 50 percent or more of the fingerprints recovered from a crime scene in 2010 utilizing laboratory-based processes.

3. Identification Patterns for Fingerprints:

Dactyloscopy, the scientific term for fingerprint identification by comparing the skin imprints of two fingers or toes, the palm of the hand, and the sole of the foot, may help determine whether the prints belong to the same individual. Even if two fingerprints or palm prints are captured from the same hand within a few seconds of each other, no two fingerprints or palm prints are ever exactly the same in every detail. Fingerprint identification or individualization (or toe or sole) is a phrase used to describe the process of using threshold scoring methods to assess if two friction ridge imprints are likely to have originated from the same finger or palm [34].

Rolling black printer ink over a white background creates contrast, which makes it possible to capture friction ridges on film with purpose. It is possible to digitally record friction ridges on a glass plate using the Live Scan technology. For example, the accumulation of friction ridges might lead to the formation of a "latent print" on the surface of anything like an item. Humans cannot see latent prints, which are not apparent to the naked eye, unlike "patent" or "plastic" prints. Because latent impressions are often fractured, it may be required to use chemical treatments, powder, or other light sources to make them more visible. Spotlights may occasionally reveal a latent print.

Figure 7: Analysis for Criminology.

Material that is on the friction ridges, such as sweat, oil, grease, ink, or blood, will be transferred to the surface when the friction ridges come into touch with it. There are several variables that can impact the quality of a friction ridge imprint. Variations in the appearance of a latent print from previously recorded friction ridges can be caused by several factors, including skin pliability, deposit pressure, slippage, and material used to make the surface, degree of surface roughness, and substance deposited.

Each time a friction ridge is formed, the circumstances under which it occurs are unique and never repeated. Fingerprint examiners are obliged to undertake intensive training because of these considerations. Dermatoglyphics is the scientific term for the study of fingerprints.

4. Exemplar

Fingerprints that have been taken from a subject for the purpose of enrollment in a system or as evidence in a criminal investigation are referred to as exemplar prints or known prints. One print from each finger that has been rolled down one edge of the nail to the other, plain impressions of each of the four fingers on each hand, and plain impressions of each thumb are typical example prints during criminal arrests. Live scans or ink on paper cards can be used to collect exemplar prints.

Figure 8: Ridge Ending.

Figure 9: Bifurcation.

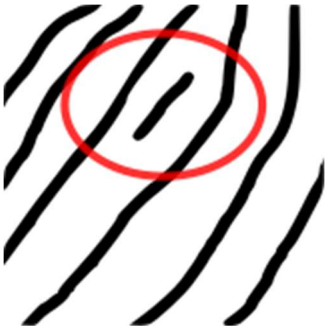

Figure 10: Short Ridge.

5. Latent Fingerprint:

So-called "latent fingerprints" are those that are only partially visible after the fingerprint has been taken from the surface of a target. Glass, for example, has a tendency to show fingerprints that have been smeared by perspiration or grease. In order to discover them, you may need to use a chemical development, such as powder dusting, spraying ninhydrin, emitting iodine fumes, or sopping silver nitrate. For each surface or substance, there are several chemical development processes. Forensic scientists use diverse ways to examine porous and non-porous materials. Transparent tape must be used after dusting to remove fingerprints from nonporous surfaces.

Forensic specialists, on the other hand, refer to partial fingerprints that can be readily seen as patent prints, rather than latent fingerprints. With a little bit of chocolate, toner or paint or ink on your fingernails, you can create a patent-related fingerprint. Latent fingerprint impressions on soft substances like soap, cement, or plaster are referred described as "plastic prints" by forensic professionals.

Forensic scientists have used it to track down people who have come into touch with a surface gathered at the scene of a crime, including suspects, victims, and witnesses. Fingerprint identification replaced anthropometric measurements in the criminal record repository as an

important method in the late nineteenth century because it was more trustworthy. To identify criminals, governments throughout the globe have depended on fingerprinting for more than a century now. Criminals are often identified primarily via the use of their fingerprints by law enforcement agencies [35].

Forensic fingerprint evidence has been questioned by academics, judges, and media alike. Standard operating procedures for fingerprint examiners in the United States have yet to be developed. Fingerprint matching is only permitted in some countries provided specific criteria are satisfied by the examiner [36]. In England, 16 identifying points are needed to match two fingerprints and identify a person, while 12 are required in France. Because of the emphasis on matching individual fingerprint attributes rather than the location of fingerprint characteristics, several fingerprint examiners have advocated against employing point-counting techniques. Fingerprint examiners may also uphold the "one dissimilarity theory," which argues that if two fingerprints vary by one iota, they are not from the same finger. Additionally, academics have expressed their displeasure with fingerprint matching. Furthermore, there has been a widespread belief that fingerprint evidence lacks a statistical foundation. Research has been done to see whether fingerprint experts can concentrate objectively on feature information without being misled by extraneous information such as context [37].

6. Encryption of fingerprints:

Fingerprints may be identified using ridge and valley patterns. When it comes to biometric identification, fingerprints have long been the most widely utilised method because of their uniqueness and durability. Although it was originally developed for use by law enforcement, an automatic fingerprint verification system is now being used by the general public. Despite its widespread use, a great deal of research has gone into pattern recognition and image processing in the pursuit of reliable automated fingerprint verification. Using the broad pattern of ridges and

valleys, or the tiny ridge discontinuities called as minutiae, fingerprints may be identified. A fingerprint's tiny traits were the most reliable and distinguishing feature in the 2000s. The identification of minute features is becoming more important in automated fingerprint verification systems. Automated fingerprint verification relied heavily on the ridge bifurcation and ridge termination [38].

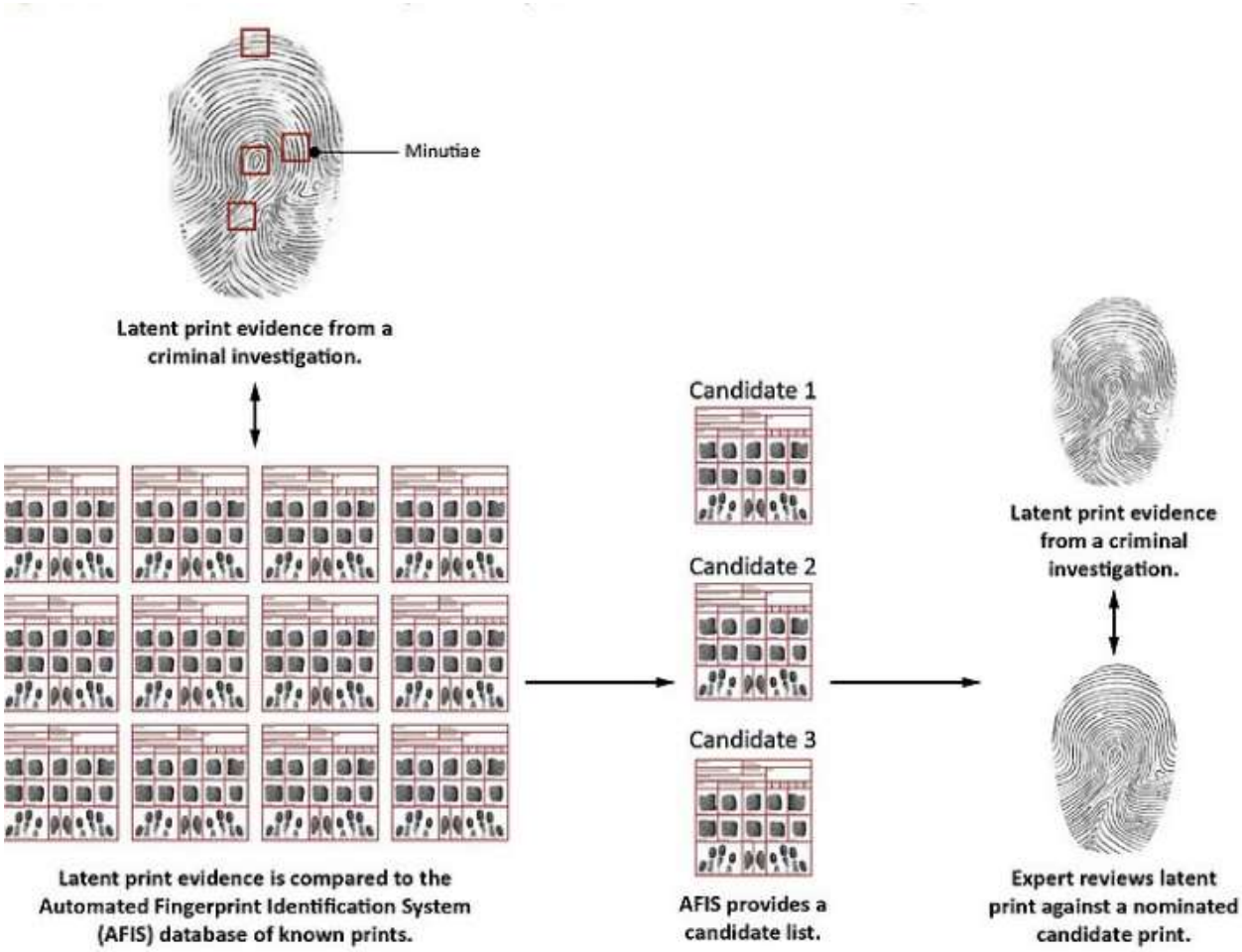

Figure 11: Latent Fingerprint.

7. Patterns:

Arch, loop, and whorl are the three most common fingerprint ridge patterns. After entering from one side, they ascend to create an arc before exiting from another side of your finger. The ridges begin on one side of a finger, form a curve, and then depart on the same side of the finger where they began.

8. Whorl:

The ridges on the finger develop in a circular pattern around a central point. There is a concept that fingerprint patterns are passed down from generation to generation, since scientists have discovered that family members typically have the same overall fingerprint patterns [39, 40].

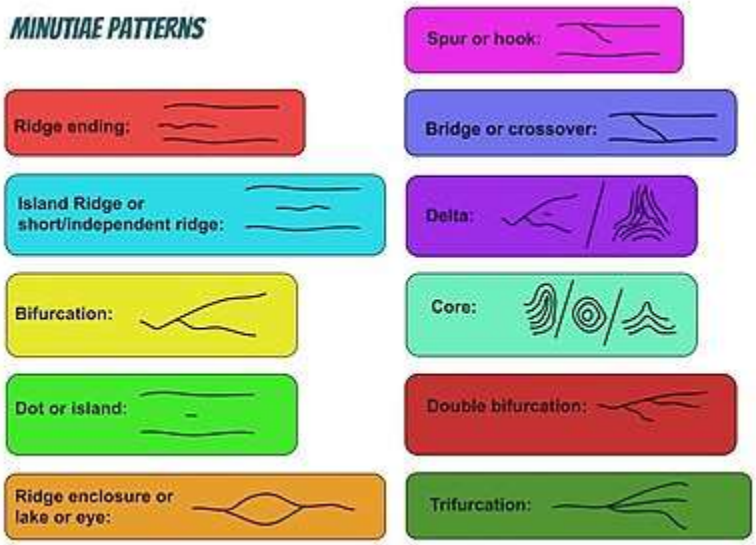

Figure 12: Minutiae Patterns.

The minutiae that make up fingerprint ridges include:

- Ending of a ridge: the abrupt conclusion

- Bifurcation: Ridge that splits into two

Ridge that starts, travels a short distance, and then comes to an end. Island or dot. An isolated, unconnected ridge within a ridge that is not part of a larger ridge.

- Enclosure by lake or ridge: A single ridge that splits in two and then returns to being a single ridge after a brief time
- A spur is a bifurcation where a small ridge emerges from a larger ridge.
- Crossover or bridge: Between two parallel ridges, a small ridge runs.
- Y-shaped ridge that meets at the delta
- The Centre of the ridge pattern is called a core.

9. Conclusion:

For every time a finger comes into contact with a surface, it leaves behind a unique set of patterns called latent fingerprints. As a result, fingerprints may be used to identify people. Fingerprint analysis has been used to identify people for over a century. SWGFAST claims that the only potential results are identification, exclusion, or inconclusive based on a fingerprint comparison. To understand more about a person, scientists may examine the chemical signals in their fingerprints. A number of detection approaches are now being investigated in order to mine the chemical composition of latent impressions for information. These methods include, but are not limited to spectroscopy and biosensors. Even though a DNA fingerprint has just been discovered, fingerprints have been the forensic field's primary method of identifying individuals for more than a century. Fingerprint evidence has been crucial in several high-profile criminal prosecutions. Criminals make every effort to conceal evidence that is readily available to them. Since a result, fingerprints play an important role in the investigation of crimes, as they can't be simply cleaned up. Due to their uniqueness and difficulty in modifying over time, fingerprints are suitable as everlasting identifiers of human identification since they are hard to conceal. Fingerprints may be

swiftly and simply used by law enforcement and other authorities to identify people who are attempting to disguise their identities or to identify the handicapped or dead after a natural disaster. If no fingerprints were left at the crime site, there would be no proof to go on. Grappling is made simpler because of the ridges of friction on the hands and feet. Ripples depict the skin's raised parts... The medical word for them is epidermal ridges. These ridges, which take various routes, produce a variety of designs. Fingerprints are a result of impressions like this. With so many possibilities, these permutations are nearly limitless, since there are many ridges that may lead to different shapes and length of the fingerprints.

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