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Fingerprint Science: A Review on Historical And Contemporary Forensic Perspectives

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ABSTRACT:

The Forensic world has been using fingerprints as the standard for identifying people for more than a century.Even after the discovery of DNA Profiling, science of fingerprint is still considered as one of the best method for personal identification. The science of fingerprint recognition has advanced throughthe initial usage of finger-prints enormously and todaythe use of biometric data in national and international legal proceedings has surpassed other conventional methods of Forensic Science. Since decades, fingerprinting, dactylography, and dermatoglyphics had gained widespread acceptance and known as the answer to individualization, especially in forensic analysis. Individual fingerprints are intricate, one-of-a-kind, and challenging to fake. Their persistent over the period of time,uniqueness, makes them appropriate as permanent identity of Human beings. A fingerprint can easily be employed by any law enforcement or other agencies to locate those who want to hide their identities or in the case of a natural disaster, identify those who are handicapped or dead. This review discuss about the advancement in science of fingerprinting since it started till the current age of digitalization.

Keywords: *Forensics, Fingerprinting, Personal Identification, Advancement in Fingerprinting, Uses of Fingerprints*

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INTRODUCTION

The science of dactylography is growing since decades, and new techniques for capturing, lifting, and developing prints made in various field settings are always being developed [1].According to the literature, a Finger Print is an imprint made by the friction ridges present on a human finger bulb. [2]. The core of the finger-print system is the idea that each person has a unique set of ridges and grooves on the skin of their tips of their fingers [3].For more than a century, it has helped Police around the world identify offenders accurately.No two fingerprints patterns that are exactly the same have ever been recorded in a crime anywhere in the world [4]. Also monozygotic twins fingerprints differ from one another. This assertion foundation is derived from human embryology and genetics, starting with foetus.The officers took imprints from both hands' whole digits mostly in criminal cases and store them for further identification [5].

Development of Fingerprint System

According to the history, the Chinese, and the Roman cultures have used fingerprints in ancient times. The oldest known friction ridge skin imprints are thought to be fingerprints [6]. It is hypothesized that during these ancient era, artisans mistakenly imprinted their fingerprints on other ancient objects and on the brick-making clay, a process known as offline fingerprint acquisition [6, 7]. On pottery, seals, and clay tabs used to record events in the second millennium BCE in Babylon, fingerprints were found. During the rule of King Hammurabi in Babylon, law enforcement collected the fingerprints of those who had been imprisoned (1792-1750 BC) [8]. Additionally, they have been discovered in ancient Babylonian and Roman bricks and tiles, Greek and Chinese ceramics, Egyptian tomb walls, and more.

Fingerprints, handprints, and footprints were all gathered and utilised as physical investigations under the Chinese Dynasty [9]. Both the Chinese historian Kia Kung Yen and the Arab trader Abu Zayd Hasan claimed to have observed the usage of fingerprints as a means of identification before 851 CE. [10]. The eminent Persian physician Rashed-al-Din Hamadani (1247-1318 AD) observed, "Experience reveals that no two individuals have fingerprints exactly alike" in reference to the Chinese tradition of utilising fingerprints to identify people. [11].

By 702, Japan permitted its uneducated inhabitants to sign divorce documents with their fingerprints. Despite the fact that ancient people employed fingerprints, it's likely that they were unaware of their ability to individually identify people [12].

Historical Data of Fingerprints and Friction Ridges:

Friction ridge skin was first described by Dr. Nehemiah Grew in 1684.The purpose, form, and structure of the skin's friction ridge were all uniquely described by Marcello Malphigi in his book in 1687 [13]. German physician JCA Mayer established the distinctiveness of the friction ridge of skin in 1788 [14]. Dr. Purkinge categorised finger-prints into 1 to 9 in 1823 and assigned each grouping a name.After that, He created a pathway of Henry's classification system [15].

Sir William HarschelContinuing with the collection of convicts' fingerprints on agreements and transactions in India in 1877 [14].Indian fingerprint scientists named Azizul Haque and Hem Chandra Bose were principally responsible for creating the Henry classification system, which was named for their supervisor [15].

Dr. Henry Faulds wrote the first study on fingerprints in 1880 and valued fingerprints ridges for individual's identity, especially used it as proof [16].

Sir Francis Galton continued to work on fingerprints and friction ridges, and published information on examination and recognition of fingerprints, demonstrating that the likelihood of a positive error was roughly 1 in 64 billion [17].

Juan Vucetich, a central police department employee in Argentina, was another notable expert in fingerprints. He started experimenting with criminals' fingerprints and developed his own way of categorization. Argentina made history's debut, first nation to solely using fingerprints as a technique of individualise when he established the world's first finger-print bureau in 1892 & used fingerprints to identifying convicts in courtrooms [18]. It is now utilised on a global scale to identify people in cases of disputes and inquiries on the grounds of courts.

1. Types of Fingerprints Patterns

Majority of the fingerprint patterns are divided into three main categories [19]:

A) Loops (60–70% of total population): It is a type fingerprint pattern where one or more friction ridges enter on one side of the print, curve up and around, and then back down, before flowing out on the original side of the print.Loops are further sub-divided into Radial,and Ulnar types (figure 1).

(B) Whorls (about 25–35% of total population): A plain whorl has one or more ridges that form or tend to form a full circuit, two or more deltas, and at least one recurving ridge that touches or is cut by an imaginary line that runs through the inner pattern region. Whorls can be considered as spiral, double spiral, almond-shaped, Concentric, etc.

C) Arches (about 6–7% of total population): Arch fingerprints feature hills of ridges. Some arches resemble tents with pointy ends. The least frequent sort of fingerprint is one with arches.They can be simply plain arches or tented arches. Tented arches being the most rare one.

D) Composite loops (about 1%–2% of total population: Two or more distinct patterns combine to form a COMPOSITE print. A composite will only cross the ridges that make up its own pattern if a line is drawn from one point of delta to the top or cap of its pattern, despite having the appearance of a twinned loop. Consists of twinned loops, lateral-pocket loops, and central-pocket loops.

(E) Accidental: A design that differs from the arch, loop, or whorl yet has features that are shared by all three categories. It's possible that this sort of pattern meets certain criteria for two or more separate patterns. These are the patterns that cannot be categorised in any of the above division and are considered as the combination of more than one or two patterns altogether.

Loop **Arch** **Composite Twinned** **Accidental**

Figure 1: Showing Different types of Fingerprints Pattern Categories

The formation of main and tertiary ridges over the palm and fingers takes place during the first four months of intrauterine life. This process was initially reported by Bonnevie in 1924 [20].

According to Cummins, papillary ridges emerge first, then secondary ridges or the appearance of furrows between them. It is well known and widely accepted that volar pads (figure 2), protuberances of tissue that start to form on the tips of fingers during the seventh week, and the ridge pattern, on the distal portion of the palm between the digits, as well as in the thenar and hypothenar regions, occur.After the tenth week of pregnancy, volar pads become less noticeable and eventually vanish in human foetus [21].

Figure 2: SEM image showing the ventral surface of a human embryo's hand taken near the end of the second month. Volar pads are noticeable close to the digit tips. (Extracted from Atlas of Human Morphogenesis, Jirasek J, Amsterdam, 1983)

According to Kucken et al., foetus volar-skin is composed of layers of epidermis on top of an amorphous, fibrous dermis during10th to 11thweek of gestation. The base layer of epidermis that interfaces with the dermis has brief forecasts and is undulated to the dermis. Primary ridges are formed when these protrusions fold the epidermis into the dermis and quickly become more noticeable (figure 3). The future fingerprint pattern, which starts to take shape at week 16, and is made up of these basic ridges [22].

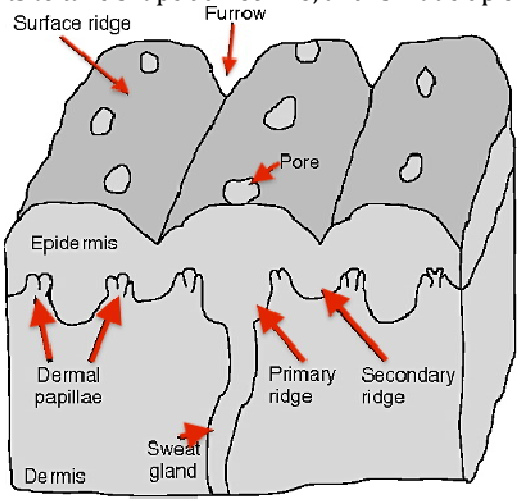

Figure 3: Structure of human skin on the finger bulb consisting of ridges and furrows.

2. Fingerprints of Twins:

Due to variances in twin new-borns', each fingerprint is distinct. There are possibilities of Monozygotic or Heterozygotic twins. Monozygotic twins are also called as Identical Twins. Across all populations, the prevalence of identical twins is 0.4%.

As Jain et al. shown by reporting the 94 pairs of identical twins, a technique for fingerprint identification may be utilised to distinguish between identical twin fingerprints.Han et al., [23] discovered after studying 66 pairs of twins that fingerprints can distinguish between identical twins with a negligible performance error. The similarity of twin fingerprints is greater than that of two randomly chosen fingers, according to Srihari et al. [5].

3. Sexual variations of fingerprints:

The sex of the individual must be established when identification is required in forensic work. The densities of the finger-print ridges and sex-based variations in finger-print pattern is now considered to be important. According to studies, women have ridges that are far more densely packed than men. The epidermal ridges on the skin of women are finer and denser than those on the skin of men [24].

4. Finger-prints at the Scene of Crime:

The goal of recording finger-prints is often used for identifying a specific individual. The individual in question can be an accused, a victim, or a witness. The three forms of finger-prints that can be discovered on a crime scene are latent-prints, patent-prints, and plastic-prints or 3D-prints [25].

To the unaided eye, latent fingerprints are invisible. The perspiration, fatty acids, amino acids, and oil on the surface of the skin are what create these prints.
We can make latent prints apparent by using dust, fumes, or chemical agents. Only finely fluorescent powder are needed for developing prints on a crime scene since fluorescent procedures are extremely sensitive on any multi-coloured surfaces [26, 27]

5. Fingerprint's Database

In order to administer a database and identify any individual, when necessary, several nations throughout the world now keep the fingerprints of people who visit, live in, and work in their countries and on borders. As a result, it is employed to identify criminals in order to protect people's lives from terrorist operations and other criminal activities. As per the current records, the Automated Fingerprint Identification System of INTERPOL contains more than 220,000 fingerprint records and more than 17,000 crime scene marks [28].
In terms of biometrics, the FBI has long been a pioneer. The IAFIS (Integrated Automated Fingerprint Identification System) is a fingerprint identification system and database run by the FBI in the US.

5.1. Databases of Fingerprint (India)

A national searchable database of criminal fingerprints is what the National Automated Fingerprints Identification System (NAFIS) project of India, a new flagship initiative being introduced in the nation. As of December 31, 2020, a total of 27, 77,689 Fingerprints (FP) slips had been transferred into the NAFIS database. Each State Fingerprint Bureau, district, and Commissioner ate has received and deployed NAFIS hardware. The time-consuming job of sending actual fingerprint slips to the State Fingerprint Bureau and Central Fingerprint Bureau (SFPB/CFPB)has been abolished up to an extent with the implementation of NAFIS, which has significantly decrease the time and efforts of the fingerprint community. Further, chance prints as well as arrestee slips can now be processed at every district headquarters online instead of depending on SFPB/CFPB [29].
All of these measures will keep Indian citizens safe and secure from any criminal activity carried out by offenders while also allowing police and courts to quickly ascertain their prior criminal histories. These actions will strengthen regional and international peace and harmony in addition to preserving India's safety and security.

6. Digital Fingerprints Analysis System

The automated reading, coding, and categorization of fingerprints using computer systems is a rapidly developing field. It works by analysing light reflected off a fingerprintthat is measurable, convertible to digital data, and for the purpose of categorising and preserving data for comparison later on. Fingerprint identification's standard foundation as one of the last stages of the fingerprint matching Automatic Fingerprint Recognition System (AFIS). There are several types of fingerprint matching technology. Matching using correlation, Minutiae-based, and both feature-based and matching based technology.
To maintain a good database, AFIS or NAFIS staff needed to be taught to take high-quality fingerprints first.The main processes in this system are the collection of fingerprints, segmentation of fingerprints, enhancement of fingerprint images, identifying characteristics feature extraction, minutiae details matching, and classification of finger-prints [30, 31].

CONCLUSION

Fingerprints have the potential to play a significant role in protecting society from terrorists and criminals while also improving the quality of life for everyone. Technology advancements and more advanced use of approaches will definitely improve rapid and accurate results, even with incomplete fingerprints. The major challenges arises, when the details of particular accused or perpetrator is not present in the database. Indian Government has recently introduced the concept of 'AADHAR CARD' that includes the complete biometric of an individual including fingerprints, iris, and face geometry. To an extent, this is quite appreciable in creating and maintaining the data of citizens and to keep them safe. However, more advancement is required to achieve higher goals of integrity and versality.

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