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FINGERPRINTING AS A BIOMETRIC IDENTIFICATION TOOL: METHODS AND APPLICATIONS IN MODERN FORENSIC SCIENCE

Abstract

One of the main areas of biometrics, fingerprinting, is crucial for identifying people on a social as well as an individual basis. It is based on the examination of distinctive fingerprint traits, which offer a trustworthy way to identify identification. Technology is extensively employed in security systems, particularly in access control, border services, and law enforcement. Fingerprinting is vital because it provides quick and accurate verification processes, which are essential for preventing crime and maintaining national security. It should be noted, nevertheless, that the efficacy of this technology is contingent upon the ongoing creation and maintenance of databases, in addition to the stringent enforcement of privacy regulations. Thus, can dactyloscopy—one of the most popular biometric instruments available today—fully meet the demands of international security? What is the relevance of its development for the future of personal identity and security systems?

Introduction

Most of the modern world when it comes to forensics, law and crime is based on biometric sciences, but what are they really? The above sciences are nothing more than the identification and verification of people based on unique biological characteristics and more. Why is it so important and widespread? Because biometrics uses human traits, such as fingerprints, iris, or facial features. Biometrics in its science also deals with behavioral traits such as the dynamics of gait, the way we speak, or even the way we write. Biometrics nowadays is number one especially in security systems that we encounter every day, such as identification in electronics, banking, etc. As mentioned earlier, biometric science is divided into two main groups:

– physical features – These are features that can visually see, feel, or touch, and include iris, finger and palm prints, facial structure, jaw structure, or DNA. The above features, although they may be similar at first glance, are completely different, such as fingerprints and palm prints may be similar, but they have several different features which will be discussed later in the essay[1];

– behavioral traits – These are unique characteristics in behavior and daily functioning such as the way people write, speak or even move. These methods are particularly interesting in the context of analyzing the behavior of criminals. Human perceptiveness can prevent many crimes such as theft, because during the commission of a criminal act, a person does not behave as he or she would in everyday life, such as frequently looking around, nervous rubbing of hands, fear in the eyes, etc. It is worth noting that only specific individuals have a similar walking style, where pulling to the side or standing on one's toes, or walking with one leg outstretched, may be characteristic.

What does the identification process look like? It usually follows a few basic steps on which the services of the time are based. Initially, physical data that can be secured such as fingerprints (dactyloscopy), footwear prints (traseology), odor traces (osmology), lip red traces (cheiloscopy), auricular traces (otoscopy), etc. are collected. These traces are converted into a unique model, then compared with previously recorded databases. If there is a match, the criminal in quastion is verified, and if there is no match, another investigation is initiated.

Where can biometric science be applied? Well, science has its popularity in the fields of security, access control, finance, or identification. In the security sector, biometrics is used in monitoring systems and building access control, allowing identification of people based on their biological characteristics. In banking, biometrics can be used to authorize transactions and log into accounts, making financial operations more secure. We also encounter digital identification on a daily basis in the form of security features for platforms. The most commonly used data protection is fingerprint or facial recognition.

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1   See: M. Tomaszewska-Michalak, A. Brzuszkiewicz, P. Becella, *Does society fear modern technology? The case of biometric security*, [in:] *Problems of modern technologies in society*, T. D. Kaczmarek (ed.),Warszawa 2018, pp. 222-238.

Methodological and methodical assumptions

- The widely accepted "3N principle"—non-removability, uniqueness, and immutability—encapsulates the well-established presumptions that underpin the use of fingerprinting as a biometric identification method. Without a doubt, fingerprints are regarded as a trustworthy identity indication. Fingerprinting is a fundamental component of many research and forensic procedures since it is believed that these patterns are consistent throughout an individual's life and can be objectively confirmed. Additionally, fingerprint analysis is objectively verified and repeatable since it follows basic scientific concepts;
- with a focus on its usage for data protection and personal security, this study attempts to examine and critique fingerprinting's use as a biometric identification method in contemporary forensic research. We cannot afford to make mistakes because of carelessness or oversight in a world where technology is developing quickly. The importance of fingerprinting in identifying people, recreating crime scenes, and other biometric security technology applications is also attempted to be demonstrated and explained in this study;
- whether at airports or on mobile devices, methodical assumptions relate to certain processes and strategies used in the collection and analysis of biometric data. To enable precise analysis and comparison, fingerprints must be carefully taken using the right instruments and according to established procedures. As simply as sand slipping through one's fingers, a technician's mistake, such failing to transfer a fingerprint onto a fingerprint foil, might allow a criminal to evade punishment. Bifurcations and ridge ends are examples of intricate patterns that must be taken into account throughout the analysis process. It is essential to ensure accuracy and dependability, which is accomplished through validation procedures;
- modern forensic science uses fingerprinting extensively for a variety of purposes, such as identifying suspects, analyzing crime scenes, and securing access using biometric technology. Society can improve its safety and understanding of possible hazards by sharing knowledge on this topic.

Introduction to Dactyloscopy

What is dactyloscopy anyway?[2] At the same time, the basic and oldest forensic science, and comes from the Greek words dáktylos (finger) and skopeín (to examine/look at). It is a branch of forensic science that deals with the examination of fingerprint impressions on the palm of the hand and the lower surfaces of the feet. This investigative technique aims to determine the perpetrator of a criminal act (that is, an act

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2 See: J. Mazepa, A. Jasińska, T. Szynawa, P. Czyżewski, K. Bryniarski, B. Klepczyński, *Vademecum of a forensic scientist*, red. J. Mazepa, Warszawa 2009, pp. 131.

or omission that violates the provisions of criminal law, punishable by the legislature. In the Polish legal system, criminal acts include felonies and misdemeanors)[3].

The above teaching is based on three fundamental principles:

– uniqueness – No two people in the world have identical fingerprint patterns. The fingerprint pattern cannot be repeated in any other person in the world;
– indelibility – Fingerprint lines cannot be damaged throughout life, and only changes can occur, such as burns, frostbite, deep wounds, etc. Damage to the epidermis causes a temporary disruption, which of course, after time, returns to the original pattern;
– immutability – Fingerprint lines already formed in the fetal period, are the same throughout life, up to the state of decomposition of the human body[4].

Back to the past

Interest in fingerprints dates back to the Neolithic era in human history, although information about it can't be found in science books we know from history lessons about cave paintings. Originally, humanoid creatures used their hands to create a variety of designs in the caverns, where the reflected fingerprint lines could be seen. However, dactyloscopy did not become a more practical method until antiquity, when thumbprints were utilized as a type of signature for property transactions such as paintings or contracts. The fact that fingerprints could not be faked was also known in 14th-century Persia as fingerprints were used on a large number of official government papers. Greece, Assyria, and Japan all went through the same. Fingerprints were never used to identify fingerprints; instead, they were utilized as a seal, a distinctive symbol that attested to the rightful owner of items and the legitimacy and authenticity of papers. It wasn't until the late 17th century that the structure of fingerprints and the sweat ducts on them were investigated.

Beginnings in the police force

Dactyloscopy, like any other science, was at first highly distrusted, as there was no concrete evidence that fingerprints were unique among humans. Also in criminal cases such as murder, rape and theft, the court looked at identification evidence with great reluctance, where a perfect example is the trial of Caesar Celli in New York in 1911. It was during this period that a burglary took place, but during interrogations the man did not admit his guilt, while at the same time the police had no witnesses or cameras to corroborate his actions. The only evidence turned out to be a fingerprint on the window frame. The convict's defense attorney questioned for a very long time whether the lines in different shapes left on the window could identify the person, since the evidence of uniqueness was still not there. Because of the court's distrust,

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3   Act of June 6, 1997 Criminal Code (Journal of Laws 1997 No. 88 item 553).

4   See: J. Druszcz, M. Liberacki, *The Essence of Dactyloscopy in the Context of Police Operations*, Warszawa 2021.

during the hearing the prosecutor decided to conduct an experiment, ordered the detective to leave the room and asked 15 random people in the room to imprint their hand on the glass, and then asked only one person to leave an imprint on the desk. The detective's task was to find the person who left the mark on the wood. Within minutes, the court got a clear answer, which was true. At that point, the experiment Made such a good impression on the jury that the burglary case was carried out faster than expected.

First conviction

The year 1902 proved to be an extremely important breakthrough in the history of fingerprinting, as it was then that a man was found guilty, based on fingerprints alone. Harry Jackson was sentenced to imprisonment for up to seven years for burglary. Biometric science at the time was very fresh technology and police officials tried to avoid it as investigative evidence. However, in the man's case, they proved necessary because Harry had left his handprints on a freshly painted windowsill, where they were highly visible, so a print from the spot was sufficient evidence in the case. On Sept. 2, the man was pinpointed, because after comparing the prints from the windowsill and from the file, they turned out to be identical.

Breakthrough in identifying people

One of the most famous criminal cases in which fingerprinting played a key role is that of William West and William West. In 1903, William West was taken to Leavenworth Prison to be convicted of a crime. When he was brought into the prison system, it was discovered that another man with the same name and who looked identical, also named William West, was already in the facility. However, when fingerprints were used for identification, it was found that despite the identical names and appearance, the fingerprints of the two men were completely different. This discovery proved the uniqueness of fingerprints and convinced many institutions to abandon the Bertillon system in favor of fingerprinting. This case became a watershed moment in the history of fingerprinting, demonstrating its reliability and effectiveness in identifying individuals. Soon after, dactyloscopy began to be widely used in criminal investigations around the world, becoming a standard in identification processes[5].

Fingerprinting became the de facto global standard for identification in criminal investigations in the 20th century. Fingerprint classification systems were developed and became widely used through the efforts of pioneers such as Sir Edward Henry and Juan Vucetich. Millions of fingerprints have been collected by police agencies around the world, enabling them to quickly and efficiently identify missing persons and criminals. The acceptance of fingerprints as admissible evidence in court has

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5   See: O. Adesola, O. Abiodun, A. Miracle, *Virtual Reality: A Breakthrough in Pain Management?,* Ibadan 2019, pp. 24-33.

significantly influenced the development of several criminal cases. The well-known criminal case of William West and William West is one in which fingerprinting was crucial. William West was sent to Leavenworth Prison in 1903 to stand trial for a crime. Upon his admission to the prison, it turned out that another man with the same name and appearance was already there. Both men had the same names and appearance, but when fingerprints were used to identify them, they turned out to be completely different. Many organizations switched from the Bertillon technique to fingerprinting when it was discovered that fingerprints were unique. This case proved to be a turning point in the development of fingerprinting technology, proving its reliability and effectiveness in identifying individuals. Fingerprinting quickly gained popularity and became a standard in identification procedures, widely used in criminal investigations around the world[6].

Basic elements of fingerprint patterns

Fingerprint patterns have a characteristic arrangement of slats at different distances, depending on gender. In women, the height of the slats ranges from 0.1mm to 0.4mm and widths from 0.2 to 0.5mm, while in men the height of the slats ranges from 0.1mm to 0.5mm and widths from 0.4mm to 0.7mm[7]. The arrangement of such lines is unique to the other person in the world, thus creating a unique pattern. However, three types of patterns can be distinguished throughout the world:
  – arched – It has no delta in the design, and the lines are arranged, as the name suggests, in an arc;
  – loop (right/left) – It has one delta, depending on whether the pattern is loop right or left, and the delta is on the opposite side, the lines together form a loop pattern;
  – vortex – Has a minimum of two deltas, and the pattern is arranged in the shape of a vortex.

   The basic elements in fingerprints are delta, base and cover but what is it? The delta is nothing more than the point at which two fingerprint lines running parallel diverge with one of them not running horizontally towards the opposite side of the pattern and the other diverging upwards and, after rolling an arc, falling to the opposite side of the pattern. These lines together separate to form something in the image of a triangle. The base, in turn, is called the horizontal arrangement of fingerprint lines, which finds its place between the lower arm of the delta and the phalangeal bend of the finger in question. The lid, on the other hand, as the name suggests, is the upper part of the fingerprint lines located above the upper arm of the delta[8].

6   See: L. O'Gorman, *Fingerprint verification*, [in:] *Biometrics. Personal Identification in Networked Society*, A.K. Jain, R. Bolle, S. Pankanti (ed.). New York 2006.

7   See: M. Szczepanik, I. Jóźwiak, *Intelligent Gateway Systems Based on Fingerprint Recognition Considering Their Damage*, "Zeszyty Naukowe Politechniki Śląskiej" 2012, z. XX, pp. 285-294.

8   See: Cz. Grzeszyk, *Dactyloscopy*, Warszawa 1997.

Group and individual features

As previously mentioned, dactyloscopy is defined by three adjectives: individuality, uniqueness and indelibility. by indelibility we mean the ability to preserve external features, but there are several ways to obliterate them:

– under the influence of mechanical actions such as a burn or a puncture wound;
– under the influence of size but the arrangement of the lines remains unchanged.

The identity of line drawings is determined by analyzing the totality of group and individual characteristics.

Group characteristics of line drawings are mainly general characteristics of the pattern, such as structure, type, genus and variety. Group affiliation is also determined by the type of delta and external term.

Individual traits are features that only some people have, in each person in a different place, such as changes in certain elements, due to mechanical actions. We distinguish between the following individual features (minutiae):

– beginnings and endings of fingerprints – Determined clockwise, and the features in question are characterized by different shapes such as rectangle, sharp-edge, circle, etc.;
– bifurcations and attachments of fingerprint lines – Defined with the direction of bifurcation of a given line, such as the point at which one line bifurcates in a clockwise direction and gives rise to two further running popular lines is called a bifurcation, and the point at which a fingerprint line bifurcates in a counter-clockwise direction is called a joint;
– bridges – this is a short segment connecting two parallel fingerprint lines, with a perpendicular line;
– hooks – this is a short segment of a fingerprint connected to a longer fingerprint;
– meshes – this is a continuous segment of the fingerprint lines, which is characterized by an abrupt bifurcation and a moment later by another joining, they usually occur in the shape of circles or ovals, but they are not symmetrical;
– dots and sections of fingerprints – them is only a small section of the fingerprint, which does not exceed 4-5 times the width of the line. Gaps – places where the course of the fingerprint is not continuous;
– contacts – this is the point where two fingerprint lines meet;
– fractures and bends of the fingerprint lines – this is a sharply defined curvature of the fingerprint line and curving in the shape of an arc;
– residual lines – running between the fingerprint lines faintly drawn thin lines;
– scars – are formed as a result of damage to the skin. They can change the appearance of the fingerprint drawing in various ways. Scars are an acquired feature[9].

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9   See: G. Kędzierska, W. Kędzierski., *Forensic Science. Selected issues of technology*, Szczytno 2011, pp. 88.

Evolution

What did it look like in the past? The development of dactyloscopy has come a very long way, constantly evolving. As far back as antiquity, fingerprints were used for such trivial things as signing documents or paintings as an individual mark, and yet at the time it was not yet known that they were separate for each individual person. Fingertips in China were initially imprinted in clay or wax, while in Babylonia, by contrast, the increasingly popular ink began to be used in the future. Depending on the authors, single fingers or whole hands were imprinted. As many people as many ideas – as the old saying goes[10]. A perfect example who marked his works in just such a way was William Herschel, who in turn discovered that the planet Uranus existed. Already at the end of the nineteenth century, the population of the world at that time began to take more and more interest in the individuality of people, so it was then that the first fingerprint classification systems were created. The person who concluded the documentation on the above subject was Francis Galton, who developed the basic minutiae, such as just loops, arcs or spirals. As it turned out later, this moment was a breakthrough in matters of identifying criminals and solving criminal cases. Initially, magnifying glasses and microscopes were used to analyze fingerprints. Experts visually compared fingerprint patterns, and descriptions were handwritten. It was only after time and the advent of further inventions, such as the camera and computer technology, that the process of comparison was significantly streamlined, as people were already being catered to by the system. A rather interesting but little-known element of past practices was the so-called „technique by telephone", where services communicated with each other beforehand through telephone interviews. Such a conversation had to involve two people who were experts in the field of fingerprinting, since, for the time, knowledge of the subject was scarce and only specially trained people were able to draw a similar or identical pattern. This was especially true in situations where information was needed for another country. In the 20th century the era of manual comparison of fingerprints came to an end, and although the process was very tedious and monotonous, thanks to it monotonność was possible to identify many criminals. Fingerprints at that time were stored in paper files, and their manual search and comparison required great precision and a great deal of time. Technology has gradually streamlined these processes, transforming dactyloscopy into one of the key methods in biometric research[11].

Summary

When inspecting a crime scene, the most important rule is: Do not obliterate or destroy fingerprint marks or other traces of forensic significance! Initially, when entering a room or an open area, look at the ground so as not to trample anything with

10 See: Tomasz Szczepański, *Dactyloscopy Through the Ages*, "Problemy Kryminalistyki" 2019, Issue 303, pp. 13-20.
11 See: S. Cole, *Suspect Identities. A History of Fingerprinting and Criminal Identification*, Cambridge 2001.

your own footwear. When grabbing any object, look at it carefully to see if any forensic traces have been left on it. Also, be sure to wear gloves so as not to leave your own marks. The use of glove protection, at first, may seem very simple, but technicians should use latex or nitrile gloves, not cloth, as cloth can also be revealed. Fingerprint marks are difficult to see with the naked eye, needing the right light, angle and objects. To enable identification tests, they should be transferred to fingerprint film, using methods:

– Physical – optical – It is based on finding the trace with the help of magnifying glasses and natural or artificial light. If the object is light, locating the trace will not be a problem, but in the case of large objects such as machinery, it is necessary to illuminate the place with light, choosing the appropriate angle;
– Physical – mechanical – It is based on the adhesion of the powder to the particles of the substance, thanks to the force of adhesion. The use of poor-quality powder or a dirty brush can cause complete destruction of traces;
– Chemical – Involves a chemical reaction between chemical agents and trace-forming substances such as blood or sweat;
– Biological\Physicochemical – Similar to the chemical method, it involves a chemical reaction. However, it should be remembered that on site the technician can not always get an "easy" substrate of a given trace, they are usually limited to using only powders. If the technician finds that the trace on a "difficult" substrate is to be secured, he should not attempt to reveal the trace with dactyloscopic powder, but send the object to reveal the trace under laboratory conditions if possible.

Balance Advantages of Dactyloscopy:

1. Durability: Identification is possible even after a few years.
2. Uniqueness: No one has repeatable palm prints with anyone else.
3. Simplicity: Palm prints are very easy and quick to take.
4. No falsity: Fingerprints are impossible to fake, as one different minutiae will be found.
5. Universality: there is a huge database with many fingerprints all over the world.

Disadvantages of fingerprinting:

1. Poor quality: Slight dirt, grime, dust and other small faults can contribute to unreadability.
2. Cost: As we know, money rules the world, and maintaining forensic stations is expensive.
3. Illegibility: There are external situations beyond our control, such as rain, which in the long run will smear fingerprints, for example, on a car window.

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