Fingerprint Recognition II
History of Fingerprinting

White Paper

Guardware

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Table of contents

Other related background documents:

White Paper: Fingerprint Recognition I – Finger Scanning: Step by Step
Backgrounder: Biometric Integration – Guardware Systems

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Fingerprint Recognition II – History of Fingerprinting
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1) Guardware Systems

Guardware Systems Ltd., based in Budapest, Hungary, was founded in January 1999 by an international group of investors. By retaining technology and innovations from previous Hungarian companies in the field of fingerprint recognition, Guardware boasts a young and flexible organization with more than seven years experience and know-how in fingerprint recognition technology.

Guardware's core technology is implemented in products ranging from computer and network protection to physical access control in the form of off-the-shelf as well as customized solutions.

Guardware targets the high-end markets demanding maximum security with fast and reliable authentication. Guardware is committed to on-going research to provide its partners and their customers with solutions possessing the highest level of accuracy and flexibility in the industry.

Biometric security from Guardware is based on advanced fingerprint recognition algorithms ensuring high and reliable performance and a durable optical scanner equipped with a unique biosensor. This biosensor – protected by international patents – recognizes and rejects finger surrogates with which intruders may attempt to compromise the system.

2) Uniqueness of Fingerprints

Fingerprints serve to reveal an individual's true identity and the practice of using fingerprints as a means of identification, often referred to as dactyloscopy, is an indispensable aid to modern law enforcement.

Through the history of fingerprinting no two fingerprints have ever been found to match exactly. If exact pattern duplication were to exist in the world, without doubt, at least a single instance would have been discovered by now.

In addition, numerous empirical studies have shown that the fingerprints of identical twins are different, as well as of triplets, quadruplets, and quintuplets. In that sense, fingerprinting is even more discriminating than DNA analysis, which, with today's technology, cannot distinguish between identical twins.

Each ridge of the epidermis (outer skin) is dotted with sweat pores for its entire length and is anchored to the dermis (inner skin). The epidermis consists of several layers. Basically, the outer layer is dead skin while the inner layer is the generating layer. The dermis contains blood vessels and is feeding the generating layer with nutrients. The dermis is covered with double rows of peg-like formations called papillae.

A human fetus starts forming ridge patterns, which follow a genetic master plan of placement of the papillae. Identical twins have the greatest chance of having the same genetic variations and to have the same papillae formations. Sometimes they are similar but just as often they are not.

In even a small area of the skin there are hundreds of papillae or ridge units, distinguished by pores in the outer skin. During fetal life, the individual ridge units start to develop and grow randomly. As they grow they start fusing together. The plethora of genetic and physical variables affecting the ridge formation is the reason that no two fingerprints are the same. The ridges formed by the papillae are commonly referred to as papillary ridges or friction ridges.

At about the fourth month of fetal life, differentiation begins and by the seventh month the ridge pattern is fully formed. Once formed, the ridge pattern never changes. Injuries such as superficial burns, abrasions, or cuts do not affect the ridge structure, and the original pattern is duplicated as new skin grows. However, an injury that destroys the dermal papillae will permanently obliterate the ridges.

3) History of Fingerprinting

Using unique characteristic traits for identification of an individual has been around as long as mankind. Tribe-members knew and recognized one another and that was the basis for deciding if someone belonged or not. The recognition was based on the characteristic traits that each of us is born with. The determination and codification of these unique characteristics has evolved into the science of biometrics.

The genesis of fingerprinting

In Nova Scotia petroglyphs (from the time of pre-historic Native Americans) showing a hand with exaggerated ridge patterns have been discovered. In ancient Babylon and China fingerprints were impressed on clay tablets and seals. In fourteenth-century Persia fingerprints were impressed on various official papers. At that time a governmental official observed that no two fingerprints were exactly alike.

Using the newly invented microscope, **Professor Marcello Malpighi** at the University of Bologna noted ridges on the surface of fingers in **1686**. He described them as loops and spirals but did not note their value as a means of personal identification. Later, in **1823** at the University of Breslau, **Professor John Evangelist Purkinje** published his thesis proposing a system of classification based on 9 different fingerprint patterns. Despite the fact that his proposed classification attracted little attention this is probably the first modern study of fingerprints.

The first modern use of fingerprints occurred in **1856** when **Sir William Herschel**, the Chief Magistrate of the Hooghly district in Jungipoor, India, had a local businessman, Rajyadhar Konai, impress his handprint on the back of a contract. Later, the right index and middle fingers were printed next to the signature on all contracts made with the locals. The purpose was to frighten the signer of repudiating the contract because the locals believed that personal contact with the document made it more binding. As his fingerprint collection grew Sir Herschel began to realize that fingerprints could prove or disprove identity. Despite his lack of scientific knowledge in fingerprinting he was convinced that fingerprints are unique and permanent throughout life.

The French anthropologist, **Alphonse Bertillon**, devised the first widely accepted scientific method of biometric identification in **1870**. The **Bertillon System**, Bertillonage, or anthropometry was not based on fingerprinting but relied on a systematic combination of physical measurements. These, among others, included measurements of the skull width, foot length, and the length of the left middle finger combined with hair color, eye color, as well as face and profile pictures. By grouping the data any single person could be placed into one of 243 distinct categories. For the next thirty years, Bertillonage was the primary method of biometric identification.

The incarnation of fingerprinting as a biometric science

Dr. Henry Faulds, British Surgeon-Superintendent of the Tsukiji Hospital in Tokyo, took up the study of fingerprints in the 1870's after noticing finger imprints on pre-historic pottery. In **1880**, in the October 28 issue of the British scientific periodical Nature, Dr. Faulds was the first to publish a scientific account of the use of fingerprint as a means of identification. In addition to recognizing the importance of fingerprints for identification he devised a method of classification as well. Dr. Faulds is credited for the first fingerprint identification – based on a fingerprint left on an alcohol bottle.

In addition to publishing his findings, he forwarded an explanation of his classification system and method of recording inked impressions to Sir Charles Darwin. Sir Darwin informed Dr. Faulds that he, because of age and illness, could not aid him in his work, but promised to pass the materials on to his relative, the scientist Francis Galton.

Through close examination of the works of Dr. Faulds and of the fingerprint collection of Sir William Herschel, **Sir Francis Galton** was able to establish the individuality and permanence of fingerprints. His book, "Fingerprints" from **1892**, contains the first fingerprint classification system containing three basic pattern types: loop, arch, and whorl. The system was based on the distribution of the pattern types on the ten fingers, e.g. LLAWL LWWLL. The system worked, but was yet to be improved with a classification that was easier to administer. Sir Galton identified the characteristics used for personal identification, the unique ridge characteristics known as minutiae, which are often referred to as "**Galton's details**".

In **1892**, **Juan Vecetich**, an Argentine Police official, made the first criminal fingerprint identification. He was able to identify a woman, who had murdered her two sons, and cut her own throat in an attempt to avoid blame. Her bloody print was left on a doorpost, proving her identity as the murderer.

Shift from Bertillonage to fingerprinting

During the 1890's, **Sir Edward Richard Henry**, a British official in Bengal believed that a fingerprinting system was the solution to his problem of verifying the identity of criminals. He began a correspondence with Sir Galton and later visited him in

England. The method with which Sir Henry developed his classification system cannot be established, but it produced 1,024 primary classifications, and was instituted in Bengal in **1897**. The system is described in his book, “Classification and Uses of Finger Prints”. In June 1897 Bertillonage was replaced and the **Henry Classification System** became the official method of identifying criminals in British India.

Transferred back to England in 1901, Sir Henry, now Assistant Commissioner of the Metropolitan Police, established the first fingerprint files in London. Subsequently, within the next 25 years, the Henry Classification System was adopted as the universally accepted method of personal identification by law enforcement agencies throughout the world. It is still in use though several variants of the Henry Classification System exist.

In 1903, Will West was sentenced to a prison term in the U.S. Penitentiary at Leavenworth, Kansas. Coincidentally, there was already a prisoner whose Bertillon measurements were nearly exactly the same – his name was William West. Their Bertillon measurements were close enough to identify them as the same person, but a fingerprint comparison could distinguish between the two men. Later, it was established that they were in fact identical twins. The Bertillon System never recovered the credibility it lost with this event.

Juan Vucetich also worked on a classification system based on the findings of Sir Galton and years of experience in fingerprint forensics. His system was published in his book, “Dactiloscopía Comparada” (Comparative Fingerprinting) in **1904**. His system, the **Vucetich System**, is still used in most Spanish-speaking countries.

During the first 25 years of the 1900s more and more agencies in the U.S. started to send copies of their fingerprint cards to the National Bureau of Criminal Identification. These files formed the nucleus of the FBI fingerprint files when the Identification Division of the FBI was established in 1924. By 1946 the FBI had processed more than 100 million fingerprint cards in manually maintained files. By 1971, this number had increased to 200 million cards.

With the introduction of AFIS technology (Automated Fingerprint Identification System), the files were split into computerized criminal files and manually maintained civil files. Many files were found to be duplicates and the records actually represented somewhere between 25 and 30 million criminals and an unknown number of individuals in the civil files.

4) Fingerprinting

Fingerprinting has been used by law enforcement agencies for more than a century to identify a perpetrator from a fingerprint left at the scene of a crime and to make positive identification of suspects taken into custody. Fingerprinting in forensic science is called latent print examination whereas the term ten-printing covers processing of inked and rolled prints on records containing full prints of all ten fingers.

In finger scanning the fingerprint is also acquired, but instead of storing the full image, only data about specific points is stored for subsequent identification. It is important to note that the difference between fingerprinting and finger scanning is not whether the process is automated, but whether the full image is stored or merely a digital representation, referred to as a template.

Latent print examination

Latent print examination involves locating and preserving impressions left by the perpetrator for his identification. On a latent print, the ridge structure is reproduced on an object in sweat, oily secretions, or other substances naturally present on the human fingers. Most latent prints are colorless so before they can be preserved and compared they must be “developed”, which is done by brushing them with gray or black powders. The latent impression is preserved either by photography or by lifting powdered prints on the adhesive surface of tape.

When comparing a latent print with the print of a suspected perpetrator, the latent print examiner goes through the procedure called ACE-V, which includes:

1) Analysis – the qualitative and quantitative assessment of Level 1, 2, and 3 details (see below) to determine their proportion, interrelationship and value to individualize.

2) Comparison – to examine the attributes observed during Analysis in order to determine agreement or discrepancies between two ridge impressions.

3) Evaluation – the procedure of comparison between two friction ridge impressions to effect a decision: match, non-match, or insufficient data.

4) Verification – an independent Analysis, Comparison, and Evaluation by a second qualified examiner.

Latent print analysis

Level 1 details includes the general ridge flow and pattern configuration and is not sufficient for individualization, but can be used for exclusion (the latent print is normally compared to a ten-print card). These basic patterns of lines can either be a loop, whorl, or arch pattern. These patterns can be distinguished by the naked eye and can give filter information for a search in the central fingerprint files.

There are several variations of the Henry Classification System; therefore there are also different sub-types of Level 1 details used for classification in different countries. Examples of loop pattern sub-types are double loop, central pocket loop etc.

Level 2 details include minutiae or Galton's Points, which are formations such as ridge endings, bifurcations (the point where one ridge divides into two), dots (very short ridge lines), and crossovers (two ridges which cross each other). The relationship of level 2 details enables identification.

Again, there are variations in classifications and types of the Level 2 details applied in different countries. The FBI (Federal Bureau of Investigation, USA) works with 8 specific types whereas the BKA (Bundeskriminalamt, Germany) works with 11 types.

Level 3 details include all dimensional attributes of a ridge, such as ridge path, deviation, shape, pores, breaks, scars, and other permanent details.

Since latent prints left at the scene of a crime very often are distorted, partial images of low quality, latent print examination is characterized by locating and matching minute details and properties of the preserved fingerprint against the suspect's inked print. Therefore, latent print examiners focus on Level 2 and especially Level 3 details.

Even though the comparison is based on objective observations, the final identification is subjective and is reached when a sufficient quantity of Level 2 and 3 details is present. To ensure the quality of the decision two independent examiners must come to the same conclusion.

Ten-printing

Ten-print identification is based on physical records containing full prints of all ten fingers. In most countries, the (presumed) criminal has his fingers inked and rolled on a card upon arrest. The card is then sent to the central register containing many millions of prints for comparison. In this way the police can see whether the person in question is operating under an alias or has previous arrests.

Finding the matching identity between the many millions of ten-prints stored in a central register requires a different approach than the ACE-V procedure alone. Therefore, the primary purpose of the ten-print procedure is to limit the number of potentially matching prints to a more workable number.

As a consequence a search in the ten-print database is performed using Level 1 and 2 details as devised by the classification system in use. After the screening, the same technique as used for latent print examination is used to establish which of the possible files is identical to the ten-print (or latent print). A vast majority of the searches in the central register is to match two ten-print records since latent prints are most often compared to the ten-print of a known suspect.

Where matching of a latent print with the central register was an immense task or impossible earlier, the use of AFIS technology has made it a lot easier.

AFIS (Automated Fingerprint Identification System)

Computerized systems managing ten-print databases are knows as AFIS. The Federal Bureau of Investigation in the USA has been working on various automated solutions since the end of the 1920's with varying success.

At first, the FBI tried to automate its fingerprint files by recording ridgeline counts (described below) on punch cards. The system was not able to match prints, but could only sort the cards into general classes. Therefore, the system was soon abandoned. The first operational system arrived at the end of the 1970's and the FBI started to scan in millions of ten-print cards.

At the FBI, one of the more than 800 fingerprint examiners start out by determining the print's classifications. Based on these classifications the computers compare the print's ridgeline count with those in the files. The AFIS starts with a rough match, then a fine match on the results, and finally proposes one or more candidates from the fine match to be checked by the fingerprint examiners.

The system still lacked search capability and through the 1980's the FBI struggled with increasing the capacity of the obsolete system based on 1970s technology. In 1989, it was decided to overhaul the entire process and a new IAFIS (Integrated AFIS) was planned, and taken into use at the end of 1999.

Searches in the IAFIS are also based on ridgeline counting as well as additional information about the suspects' description. IAFIS is more powerful and flexible in terms of searching. Since the storage standard in 1990 was CD-ROM, the IAFIS is based on an array of jukeboxes containing about 10,000 discs.

The IAFIS was inaugurated in July 1999 and is designed to handle more than 62,000 ten-print searches per day, but once up to speed it is expected to handle more than 80,000 searches per day.

Ridgeline count

The center of the papillary ridge area (sometimes referred to as the pattern area) is called the core point. The parallel ridges that surround the pattern area are called type lines. The point of initial bifurcation (split of ridgelines) or other features at the point of divergence of two type lines is called a delta.

By drawing a line from the delta to the core point, the number of ridge intersections crossed gives a ridge count. By establishing 12 ridge counts, and using the AFIS' search algorithm, the computer is able to delimit the number of potential matches to just a handful.

Ridgeline counting was devised with the emergence of punch card based computers and has changed little since. In the meantime, other methods have evolved and today it is possible to buy an "off-the-shelf" AFIS, which is able to handle the needs of a local area. Some states in the USA have already implemented small-scale AFIS systems to search their local databases, and the trend in AFIS computing move away from a centralized technology towards decentralized identification networks with an similar approach as that of the Internet.

The emergence of stronger computers through the last couple of decades has made it possible to create systems based on different technologies than ridgeline counting. One such technology is to compare vector graphic maps of the fingerprints; other technologies are comparing Level 2 details (minutiae). This, in turn, has cleared the way for finger scanning devices for computer protection and physical access control.

The mission of Guardware Systems is to enable our partners to define, create and deploy services for those demanding markets where fast and reliable identification is of crucial importance.

We believe in establishing close relationships with our partners enabling them to satisfy their customers' needs for high security authentication.

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