identification methods but is gaining increased use in digital personal identification systems based upon biometrics – a method for uniquely identifying specific people based upon measurable and permanent physical traits.

COMPARING FINGERPRINTS

Most often, fingerprints are used to compare an unknown sample, such as prints either taken at a crime scene or from someone of unknown identity, with fingerprints obtained from a known source (reference). In this fashion, the unknown prints can be unambiguously assigned to one individual person (Figure 7.2.10). The process usually involves both the general classification system (level 1) and the identification and location of minutiae within the prints (level 2). Generally, the more matching features found when comparing two sets of prints, without the addition of any unique features found only in one print, the more confidence that can be placed in the comparison, but the exact number of matches necessary for a valid identification continues to spark debate. Usually, however, most fingerprint experts seek to identify at least twelve matching points to place a reasonable level of trust in the comparison, although European courts typically require 16 matching points for a comparison to be considered valid.

No two sets of fingerprints, including the minutial features, have ever been found to be identical, even those obtained from identical twins. Early on in the use of fingerprints for identification, Galton conservatively estimated the number of possible fingerprints at over 64 billion. That would mean that the chance of two random prints being identical would conservatively be estimated at $(1/64,000,000,000)^2$ or about a $1 \times 10^{21}$ chance of two matching identical prints – an astronomically small chance.

In fingerprint matching, the ridge line patterns are usually first compared at all locations between a pair of fingerprints to determine the general pattern features (e.g., arch, loop, or whorl). Cores and deltas are also identified and located within the print and help orient the two prints for comparison. Minutiae are then similarly identified and located within the “map” of the print to complete the full picture. It is occasionally possible, however, to go beyond this level of detail and to resolve pore features and

ACE-V

ACE-V refers to a method in the identification of friction ridge impressions that follows the steps of Analysis, Comparison, Evaluation and Verification. This method has been likened to the steps central to the scientific method itself that employs the process of (1) observing and collecting data, (2) recognizing empirical relationships in the data, (3) forming a hypothesis to explain these relationships at a deeper level, and (4) testing and refining the hypothesis through carefully designed experiments.

In the ACE-V process, analysts typically begin by initially looking at a fingerprint in question to find recognizable features, such as loops, bifurcations, etc. Once these features have been “located”, the print can then be compared with a reference fingerprint to identify both similarities and differences. Once this has been completed, then the degree of the “match” in the features between the unknown and the reference print can be evaluated. Finally, the degree of match or non-match between the two prints should be verified by another analyst to verify the subjectivity of the analysis.

The use of this approach has, however, come under scrutiny recently and it has been argued that with this approach would “guarantee precision or application, [but] not accuracy of conclusion”. This doubt has been reinforced by a recent court decision has found that the ACE-V method has not yet met the Daubert standard in itself [U.S. v. Plaza, Acosta and Rodriguez, United states District Court for the Eastern District of Pennsylvania, Cr. No. 98-362-10.11.12, March 13, 2002, pp. 48.].
locations in the ridges and also imperfections in edges of the ridges, usually from electronic scanning methods rather than other sampling methods (see below). Work is in progress to use this information in a way similar to how minutiae are employed in print comparison. Some features, such as scars and creases can be used but they are often changeable over time and are, therefore, of limited use. There also appears to be a relationship between fingerprint patterns and ethnicity with Europeans and Africans displaying relatively high incidences of loop patterns and Asians and Australian aborigines showing whorls.

The Prints of the Master: DaVinci Unknown Treasure?

Have all of DaVinci’s works been found and catalogued almost 500 years after his death in 1519? According to some, at least one recently discovered work is an unknown masterwork of Leonadro DaVinci’s that somehow missed everyone’s attention. The work, entitled La Bella Principessa, is a beautiful work of ink and chalks on vellum (treated animal skin). But how to determine if it truly a lost masterwork?

As it turns out, the artist of the questioned work left a partial fingerprint in the upper corner of the drawing (at right). This partial print has been compared to fingerprints left on a early known work of DaVinci called St. Jerome in the Vatican collection. The problem is the quality of the print on La Bella Principessa. At this point, experts agree that it is indeed a fingerprint on the questioned work, but disagree as to any match between the print and those found on the St. Jerome painting, some say yes but others disagree. The stakes, however, are very high upon any identification. The work was purchased in 1998 at auction for $19,000 but has been estimated to have a value of $150,000,000 if it an indeed an unknown DaVinci work. But for now, the question still remains undecided.

Computerized Methods: IAFIS, NGI, and Beyond

In the past, fingerprint comparisons involved long and laborious work of visual identification and comparison of features. This has changed and most comparisons are now done using computer-assisted methods. In the United States, the FBI maintains an electronic database containing the fingerprints of millions of people in its Integrated Automated Fingerprint Identification System (IAFIS), the largest such database in the world with over fifty million ten-print fingerprints currently in the system and growing daily. These computer-based methods quickly and efficiently match fingerprint features between an unknown print and millions of records in the database, known as a one-to-many matching process, and are able to provide information about the individual person found with the matching fingerprint (e.g., prior criminal record, gun purchases, etc). The system is frequently used in employment background checks, verifying legitimate firearms purchases, identifying remains, and in criminal investigations. The system is heavily used and has performed as many as 100,000 matches in a day.

The FBI is in the process of replacing IAFIS with a new and enhanced automated system to be called the Next Generation Identification System (NGI) that will integrate many types of personal identification data, including fingerprints, eye-scans, and facial imaging methods, to permit expanded capabilities for the extremely fast identification of people for both criminal and security purposes (Fig. 7.2.11).
The process of entering fingerprint information into the IAFIS system uses a technique called either *Live Scan*, for taking high resolution prints directly from a subject, or *Card Scan*, for digitally scanning previously taken prints (Fig. 7.2.12). The process is similar to how digital cameras take pictures. In either case, the prints are digitized and the computer identifies the patterns and minutiae in the print for comparison with other prints in the database (Fig. 7.2.13). Often, prints that carry similar features to the sample being compared are provided by the computer search along with some measure of the degree of certainty in the comparison. IAFIS has an estimated error rate of about 2%.

**USES OF FINGERPRINTS: IDENTIFICATION VS. AUTHENTICATION**

Fingerprint information is used typically for one of two main tasks: *identification* or *authentication*. While these may sound very similar, the process and ultimate answers provided can be quite different.

Identification refers to specifically using fingerprints to identify an unknown person from a set of prints. The main issue here is to identify uniquely a set of “unknown” fingerprints by matching features in the unknown to candidates in a very large pool of possibilities, often many millions of records (called *one-to-many matching*). In forensic work, this may arise when a fingerprint is found at a crime scene that needs to be identified. It is also commonly associated with determining the identity of a set of unknown human remains at autopsy.

Authentication (sometimes called verification) using fingerprints, in contrast, focuses upon comparing a set of fingerprints from a person with either just one reference set or among a very small number of “standard” possibilities. This can be used as part of a biometrics security scan at an airport or trying to identify return offenders to the criminal justice system. This process is often referred to as *one-to-one matching*. The process usually begins with a “known” person giving their fingerprints...
that forms a biometric reference template that is linked to their “known” identity. Then, at a later time, when their identity needs to be confirmed, such as to log into a computer or bank account (Fig. 7.2.14), a new scan is taken and the template from this sample scan is compared just to their single reference template. A match then allows the person access to the restricted account or “authenticates” their identity, such as in repeat offender identification (Fig. 7.2.15).

**OBSERVING FINGERPRINT PATTERNS**

The collection of fingerprints are classified into three major types depending on how they are formed and visualized. These are usually referred to as visible prints, latent prints and impression (or plastic) prints.

**Visible prints.** As the name implies, visible prints are those that are readily seen by the naked eye. These are typically made by the transfer of the print using a visible medium, such as ink, paint, blood, or dirt, to a surface where it is directly observed. This is very similar to a printing process where the ridge patterns serve as the “type” to transfer the medium to the paper. It is also the method used when preparing inked reference prints for later comparisons, such as shown in Fig. 7.2.16 and 7.2.17. Visible prints can also be found at crime scenes where a persons hands or fingers come in contact with a visible liquid, such as ink, paint or blood, and then they transfer their fingerprint pattern by touching a smooth surface, such as shown in Figure 7.2.18.
**Latent Prints.** When we touch an object with our fingers, some of the oils, water, and amino acids on the tops of the ridges can be transferred to the object. This process imparts an invisible pattern of oils and amino acids to the surface that, with proper techniques, can be made visible. These prints are called latent prints, or prints “waiting” to be made visible.

Numerous techniques have been developed to help visualize these latent prints. One of the simplest techniques is to simply “dust” a very fine powder across the surface containing the prints using a fine brush (Fig. 7.2.19). The fine powder sticks to the oils and moisture in the latent prints. When the excess powder is removed from the area, only the places where the oils and moisture trapped the dyed powder remains behind to show the detailed fingerprint. Many types of powders are available with different colors and properties (Figs. 7.2.20 and 7.2.21) and are chosen to accentuate the latent print from the background material, including those that contain a fluorescent dye that can be visualized using an ultraviolet light (Fig. 7.2.22) to make the print visibly “glow”.

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**Figure 7.2.18.** Visible hand and fingerprints in blood from crime scene ([http://www.staffs.ac.uk/schools/sciences/forensic/forensicfacilities/handprint.jpg](http://www.staffs.ac.uk/schools/sciences/forensic/forensicfacilities/handprint.jpg)).

**Figure 7.2.19.** Brush for applying fingerprint powders for visualization of latent prints ([http://www.evidentcrimescene.com/cata/latent/latent.html](http://www.evidentcrimescene.com/cata/latent/latent.html)).

**Figure 7.2.20.** A sample of the wide variety of powders available for visualizing latent prints ([http://www.dojes.com/images/powders_small.jpg](http://www.dojes.com/images/powders_small.jpg)).

**Figure 7.2.21.** Application of magnetic powders for latent print visualization ([http://www.casualtsimulation.com/gallery/v/forensics/standard-magnetic-fingerprint-powder-applicator/](http://www.casualtsimulation.com/gallery/v/forensics/standard-magnetic-fingerprint-powder-applicator/)).

**Figure 7.2.22.** Fingerprint made visible using a fluorescent powder and illuminated with an ultraviolet light ([http://scienceandresearch.homeoffice.gov.uk/fingerprint.jpg](http://scienceandresearch.homeoffice.gov.uk/fingerprint.jpg)).
A very similar method employs a very fine magnetic powder that similarly adheres to the oils and moisture in the latent print. The excess powder, however, is cleanly removed by passing a magnet across the surface to extract any unadhered powder from the print, as shown in Fig. 7.2.21.

Another important way to visualize latent prints is to react the oils, amino acids or salts in the transferred fingerprint with some chemical reagent that allows us to see the print. The salts and amino acids deposited from our fingers and hands are essentially non-volatile and have been shown to remain in place for decades to render clear fingerprint patterns. Many such methods have been developed but four are particularly interesting and useful.

One such method involves spraying a chemical called ninhydrin onto the surface containing the print. The ninhydrin reacts with the amino acids found in the print and, upon gentle heating to speed up the otherwise slow chemical reaction, forms a typically purple/blue-colored pattern of the fingerprint (Fig. 7.2.23).

Another common reagent used in a similar fashion is iodine. Elemental iodine (I₂) reacts readily with the oils left behind from our fingers to form a somewhat transient, but usually observable, brown color where the finger oils were deposited. In much the same fashion, silver nitrate (AgNO₃) reacts with chloride, usually from the salts sweated from the finger pores, to form the black silver chloride compound (AgCl) that shows the print. Finally, a very common reagent used in this method is cyanoacrylate, commonly known as super glue. In this technique, the object suspected of containing fingerprints is placed in a closed “fuming” chamber (Fig. 7.2.24) where it is exposed to a vapor of cyanoacrylate. The cyanoacrylate then reacts with the amino acids in the print to form a clearly observed white residue, as shown in Figure 7.2.25.

The success of making latent prints visible largely depends upon the nature of the surface to which they have been transferred. Smooth, non-porous surfaces, such as glass, metal, plastic or polished stone, usually provide an excellent opportunity to visualize the print. Porous or irregular