5 Fingerprint Analysis

Fingerprint recognition is one of the most popular biometrics methods [FBI1984, Jain1999g, Newh2000]. It traditionally serves as a secure means of verifying the identity of a person. Regarding the range of all possible biometric measures, the best understanding, the best long-term experience and the largest databases can be obtained by the fingerprint identification method. It is not surprising to find, that fingerprint recognition is the most widely used biometric measure [Newh2000]. A fingerprint resembles the ridge structure on the fingers. The sweat glands in the dermis emit a water-based oil suspension through the pores. This liquid covers the papillary ridges and leaves a latent print on a surface when touched by the finger. Every person has unique fingerprints according to scientific studies with a large amount of data. The pattern of interchanging elevations and furrows in the papillary cells is built at random in a fetal stage, which means that even monozygotic twins or cloned persons would have different fingerprints. Obviously, there was no evolutionary pressure to prefer certain patterns in a selection process using Darwin's terminology. The ridges on the epidermis, the upper layer of the skin, grow from the deeper skin layer, the dermis, and are steadily reproduced. Minor cuts, burns and injuries, therefore, will only alter the fingerprint appearance for a limited time, whereas the pattern will stay the same over a person's lifetime. This makes it an ideal feature for identification purposes.

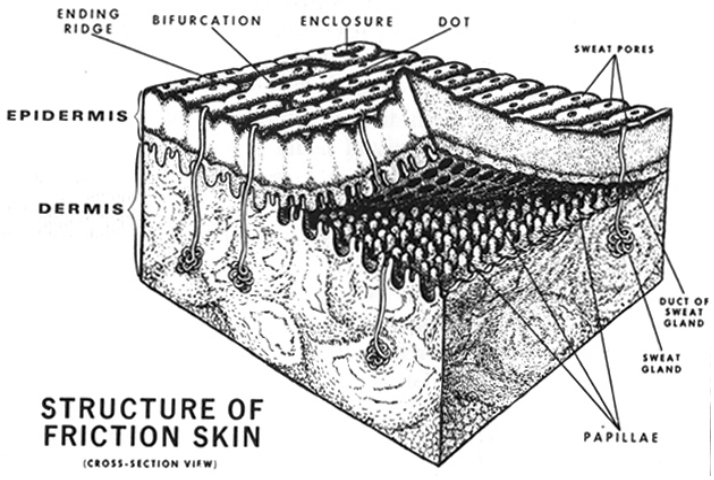

Figure 5.1: Structure of friction skin, from [FBI1984]

5.1 History of Fingerprinting

In ancient China, fingerprints were used to predict an individual's future and read his characteristic traits, like consciousness, fortune and dexterity [Laufer2000]. The religious use of fingerprints in China had been recorded long before the Christian era. The oldest artifacts with intentional fingerprint impressions and artificial pictures showing fingerprint patterns,

can be backdated to 6000 B.C. [Berr1994]. Today, it is unprovable, if the Chinese were already aware of the fingerprint's uniqueness in this era. In the age of the Tang Dynasty (618-906 A.D.), fingerprints were reported to have marked documents and in the Sung period (960-1178 A.D.), wax impressions of fingers and thumbs were used as a seal of originality [Laufer2000]. At least, this provides some evidence, that the fingerprints were considered to be characteristic of a person.

The scientific foundation of friction ridge identification originated in the late 17th century in Europe, when forensic scientists and doctors first discussed and illustrated their recognition of ridges on palms, fingers and thumbs. Two early pioneers were the medical doctor Nehemiah Grew, with his 1684 report for the Royal Society of London [Grew1684], and the anatomist Govard Bidloo from Holland, with his book on human anatomy in 1685 (see [Ashb1991]). The Italian anatomist Marcello Malpighi examined the ridges through a microscope and noticed different pattern formations [Malp1686].

It was not until 1823, when Joannes Evangelista Purkinje, a Czech physiologist and biologist observed the uniqueness of fingerprints and worked out a first classification system [Purkinje1823]. In 1880, two important letters on fingerprints were published in the scientific Nature magazine. The Scottish physician and surgeon Dr. Henry Faulds contributed with his studies on the permanence and uniqueness of fingerprints in his article „On the skin-furrows of the hand" [Faulds1880]. One month later, Sir William Herschel reported he had used fingerprints since 1858 as marks of originality on contracts and for pension distribution [Herschel1880]. Fingerprints were soon suggested as a means to identify prisoners and criminals.

In 1892, Sir Francis Galton published the first comprehensive scientific study on fingerprinting [Galton1892]. He did not only propose an original classification system [Galton1890] and verify Herschel's claims empirically, but was also the first to detect certain characteristic feature structures, which today are referred to as the so-called *Galton details* (see section 5.4). After the publication of his popular book "Finger Prints", it was proved that the ridge arrangement of every person on every finger is different and remains constant over a person's lifetime – the two basic principles which fingerprint identification relies upon.

A few years later, Sir Edward Henry devised a comprehensive method for filing and classifying fingerprints [Henry1905]. With some modification, the Henry system (see section 5.3) has been followed in nearly all English-speaking countries, adopted by the Federal Bureau of Investigation (FBI) and is still used in forensic sciences and AFIS-systems today [Ashb1991, FBI1984]. Every fingerprint is assigned a certain class according to its global ridge flow pattern.

Law enforcement has been using fingerprints to identify perpetrators since the beginning of the 20th century. Latent prints were initially lifted with the aid of powder and tape, and prisoners filed with inked prints. Forensic applications were officially accredited to use fingerprinting as a means of identification. The FBI introduced the ten-print cards[20] to enroll

[20] See Appendix 11.1.

all fingers of a criminal subject and collected millions of fingerprints. Today, the FBI's database comprises more than 227 million cards[21] [Scigliano1999], which makes positive identification a difficult task. Great strides have been made to build Automated Fingerprint Identification Systems (AFIS) in the past 15 years. Now the work culminates in the *IAFIS*[22]-project, which holds the promise of soon allowing the identification of latent prints and live scans with any digitally recorded ten-print card.

With the advent of passports, some countries traditionally required the bearer to record his thumbprint on the passport. Welfare as well as border and immigration control were the next applications that started using fingerprint recognition as a means of identification.

In the last two decades, many live fingerprint scanners and automated verification systems have been developed. Now that we have affordable sensors, a good understanding of the technology and enough reliable systems at our disposal, civil applications become accessible to biometrics [Newh2000, Jain2000a]. Fingerprint verification has already become popular in some areas such as access control, financial security and verification of firearm purchasers and driver's license applicants [FBI1984, Lee1991]. In other applications, such as ATM card verification, first pilot systems have been installed to test its performance and acceptance. The wide use of fingerprint verification in open applications seems to be quite imminent and reveals new challenging tasks, like performing the matching process in security tokens carried out in this thesis.

5.2 Basics of Fingerprint Analysis

This section explains the basic technical terms of fingerprint recognition[23]. For a detailed study of manual fingerprint examination, literature is presented in the references [Ashb1991, FBI1984, Safe1998, Olse1978, Ashb2000, Cowg1992, Durh1991].

Pattern Area:
The *pattern area* is defined as the main part of a fingerprint surrounded by the type lines. It is shown in figure 5.2.

Type Lines:
The two ridges, which start parallel on one side of the fingerprint and then diverge are the *type lines*. They define the pattern area and may not be continuous. If a break in the type line ridge occurs, the nearest ridge lying outside is considered a continuation.

[21] That means, the number of fingerprints the FBI has, totals 2.27 billion.

[22] IAFIS stands for Integrated AFIS.

[23] The examination of fingerprints employed as a method of personal identification is also referred to as *dactyloscopy*.