The Biometrics Fingerprint Sensor

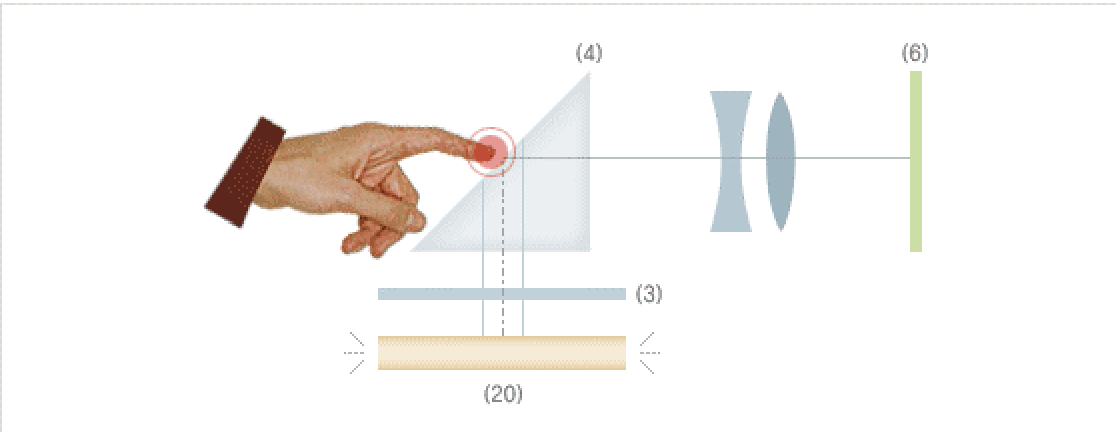
There are two main types of sensors for inputting fingerprints. One is an optical sensor using a prism or hologram, and the other type is a non-optical sensor. Recently, products employing both optical and non-optical methods have been introduced. In the past, a semiconductor sensor was the only non-optical choice, but now equipment with ultrasonic sensors, another type of non-optical sensors, is on the market.

Optical Fingerprint Sensor

Absorption

Figure 5.1 explains the basic principle of absorption in an optical fingerprint sensor.

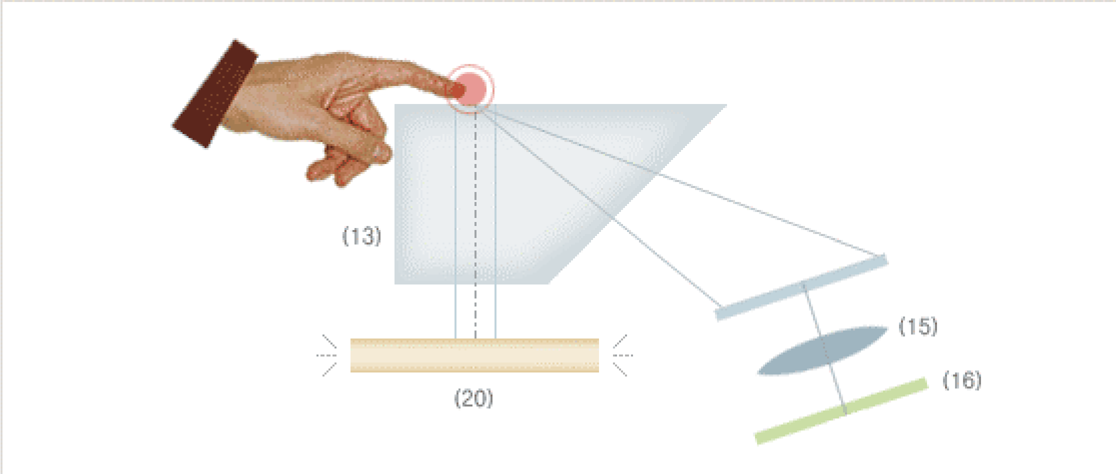
* Figure 5.1 Principle of Absorption in Fingerprint Sensor



An absorption optical fingerprint sensor is composed of **a right-angled triangle prism (4), light source (20), a diffusion plate (3), a lens group and an image sensor (6).** When a fingerprint is placed on the contact surface, its ridges are closely pressed onto the surface while its valleys are detached from it. The light radiated from light source becomes uniform after undergoing the diffusion plate. The light reaches the fingerprint contact surface after passing through the prism. If the light touches the valley, total internal reflection happens so that it reaches the image sensor composed of CCD (Carge Coupled Device) element or CMOS (Complementary Metal Oxide Semiconductor) element after going through the lens group. On the other hand, if the light reaches the ridges closely pushed onto the surface, some light goes to the image sensor after the total internal reflection and some light is absorbed in the ridges.
There are changes in luminous intensity between light reflected from valleys and light from ridges and the image sensor obtains the fingerprint image by calculating the changes in the reflected light intensity between the two. The absorption optical fingerprint sensor needs several LEDs (15-20) since the light should be two-dimensionally uniform after going through the diffusion plate. To capture a fingerprint image without distortion brought on by different optical paths, enough distance is required between the prism and the image sensor.

Scattering

* Figure 5.2 Principle of scattering fingerprint sensor

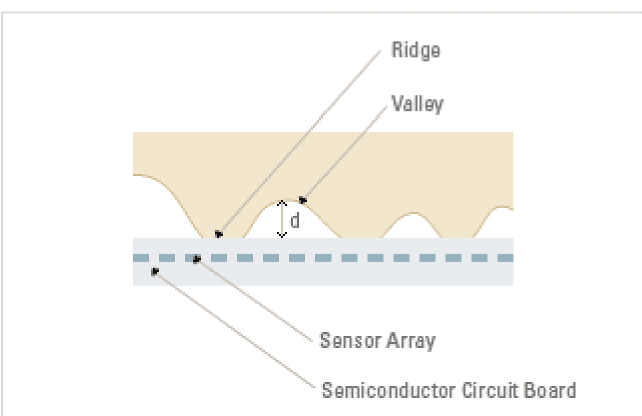


The scattering optical fingerprint sensor is mainly comprised of **a rectangular-triangle prism (13), light source (20), a lens group (15), and an image sensor (16).** When a fingerprint is placed on the contact surface, its ridges are closely pressed onto the surface while its valleys are detached from it. The light radiated from the source passes through the prism and reaches the surface. The light perpendicularly goes through the surface unlike the absorption sensor. If the light reaches the valleys, it goes through the surface, radiating to the outside. If it touches upon the ridges, scattering happens at the ridges. The scattered light gets to the image sensor composed of CCD or CMOS element through the lens group. The light radiated to outside near the valleys seldom reaches the image sensor. Only the scattered light near the ridges gets to the sensor. As a result, a fingerprint image can be captured since the valley area is dark and the ridge area is bright.
The scattering optical fingerprint sensor doesn't need a diffusion plate and its contrast is great. However, it needs the rectangular prism, more expensive than the triangle prism.

Semiconductor Fingerprint Sensor

A semiconductor fingerprint sensor is a prime example of non-optical sensors. Figure 5.3 shown below describes the basic principle of the semiconductor fingerprint sensor.

* Figure 5.3 Basic principle of the semiconductor fingerprint sensor



The semiconductor fingerprint sensor measures the electrostatic capacity between sensor surface and skin, and translates it into an image. If a user places his or her fingerprint on the surface, its ridges are closely pressed on the surface and its valleys have some space from the surface. In the case of the ridges, the distance (d) between ridges and surface is short so that the electrostatic capacity is high. On the other hand, the valleys are distant from the surface compared to the ridges, so the electrostatic capacity is low.

The fingerprint image can be captured by composing signals obtained from an array of sensors on the semiconductor surface. The semiconductor fingerprint sensor can be lighter and smaller. But it is vulnerable to external shocks and chemical substances such as sodium chloride from people's skin due to the physical traits of a silicon wafer, which is fundamental to the sensor. To address these disadvantages, the contact surface is being coated. Developing a physically strong coating is one of the major tasks facing semiconductor fingerprint sensors.

* Table 5.1 Comparison between optical and non-optical methods

Classification	Optical Sensor	Semiconductor Silicon Sensor
Recognition means	Light	Pressure
Advantages	Very safe. High perception rates. Strong against external shocks and scratch.	Impossible to duplicate. Recognizing for all types of skin quality, such as dry or moist, dirty, child's, even worn-out skin. Able to minimize the size. Low production and maintenance costs.
Disadvantages	Relatively big module. High production and maintenance costs. Require clear and good quality skin.	Sensitive to environmental changes such as temperatures.

Fingerprint Minutiae

As shown in Figure 5.4 below, the flows of the black lines are called ridges. Space between the nearing ridges is called a valley. The flows of the ridges that continue or are divided constitute a particular finger-print. An ending point is the point at which a ridge ends, and a bifurcation point is the point at which a ridge is divided into two ridges. These points are called minutiae and are really important information for the classification of an automatic fingerprinting system. There are also other important points for bulk fingerprinting DB:a core point at which the highest or lowest ridge is shown and a delta where three ridges from three different directions converge. Figure 5.4 shown below displays the minutiae on an actual fingerprint image.

* Figure 5.4 Minutiae in the actual fingerprint image

Fingerprint Recognition Algorithm

To verify the identity of a user by automatically extracting minutiae from his or her fingerprint image, a fingerprint recognition algorithm is required. The fingerprint recognition algorithm is composed of two main technologies: image processing technology that captures the characteristics of the corresponding fingerprint by having the image under-

going several stages, and matching algorithm technology that authenticates the identity by comparing feature data comprised of minutiae with Templates in a database.
Figure 5.5 shown below explains the overall block map of the fingerprint recognition algorithm consisting of the two technologies.

* Figure 5.5 Block map of the fingerprint recognition algorithm consisting of the two technologies

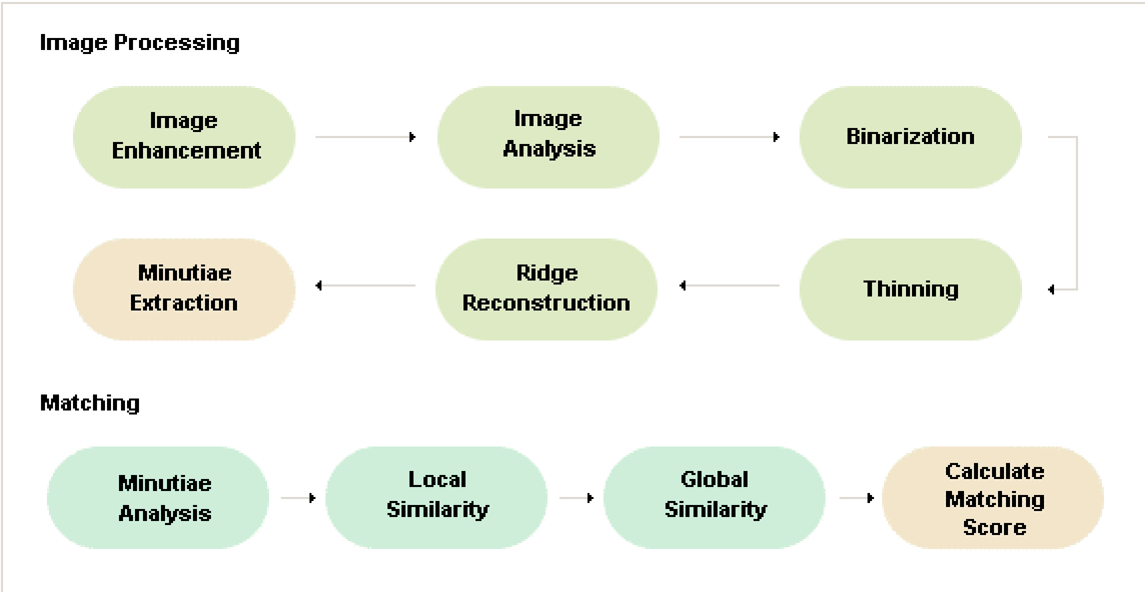
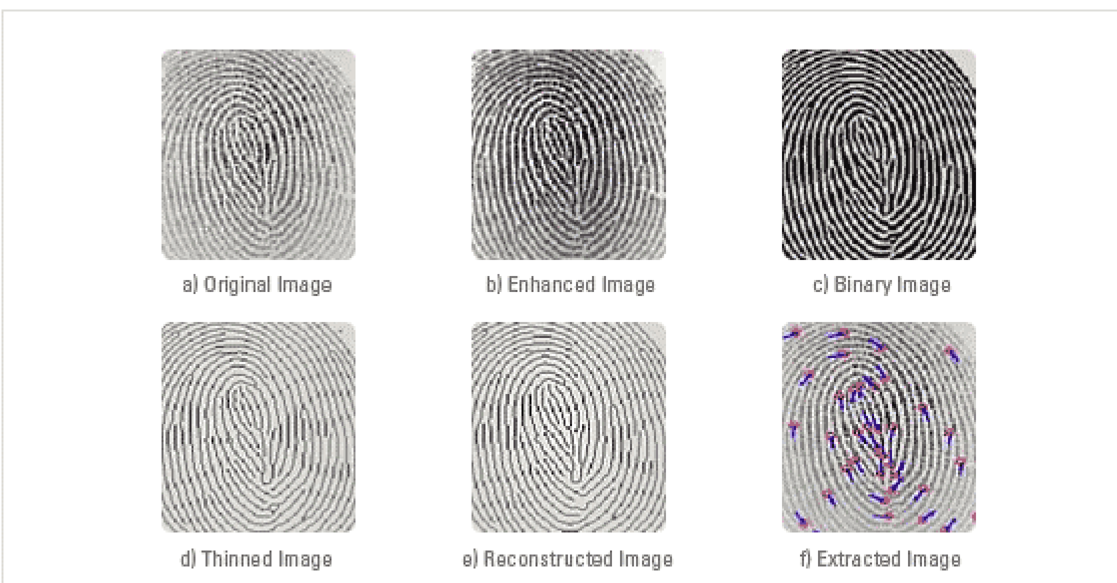


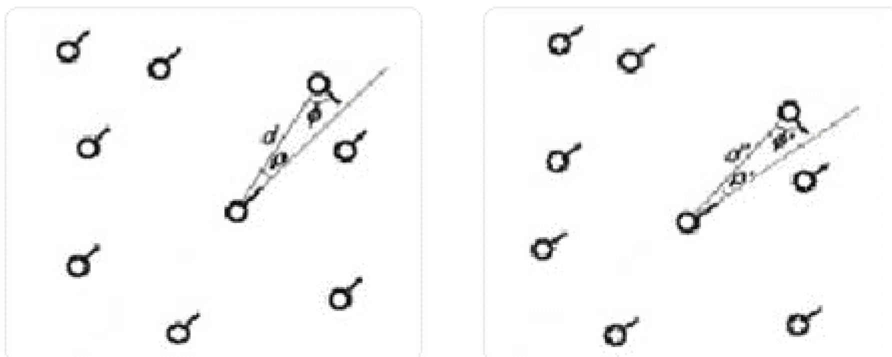
Image Processing

This part consists of six stages. At the image enhancement stage, noise on the input fingerprint image is eliminated and contrast is fortified for the sake of successive stages. At the image analysis stage, area where fingerprint is severely corrupted is cut out to prevent adverse effects on recognition. The binarization stage is designed to binarize a gray-level fingerprint image. The thinning stage thins the binarized image. The ridge reconstruction stage reconstructs the ridges by removing pseudo minutiae. At the last stage, minutiae are extracted from the reconstructed ridge image.



Matching

After obtaining feature data of a specific fingerprint, compare the corresponding user who is already stored in the DB with Templates. If the fingerprint is immensely destructed and only general ridges, not minutiae, can be recognized, two algorithms can be used in parallel: an algorithm based on minutiae and an algorithm based on the overall ridge shape.



(a) (b)

Matching stages show big differences according to their types although they are based on the same minutiae. Here, the most well-known matching algorithm will be briefly explained. The matching process consists of four main stages. First of all, the minutiae analysis stage analyzes the geometric characteristics such as distance and angle between standard minutiae and its neighboring minutiae based on the analysis of the image-processed feature data. After the analysis, all the minutiae pairs have some kind of geometric relationship with their neighboring minutiae, and the relationship will be used as basic information for local similarity measurement.

In Figure 5.7, picture (a) shows feature data of the input fingerprint, and (b) shows the already stored Template. Finding a similar minutiae pair in (b) against a minutiae pair in (a) is the local similarity measurement.

Global similarity measurement means calculating similarity of two fingerprints by finding minutiae pairs in the local similarity measurement in both feature data and selecting the greatest matching minutiae pairs in the feature data.
Lastly, calculating final matching scores with the global similarity value and comparing them with the previously set critical value verifies the identity of the user.