

# Retinal recognition

## Biometric technology in practice

by Ravi Das

While considered invasive and expensive, retinal recognition is still the most reliable and stable means of biometric identification. Although the advantages of retinal recognition currently outweigh the disadvantages, its widespread use is held back by public acceptance. As Ravi Das explains, there is every reason to believe that this may well change.

This article focuses on a unique biometric technology: retinal recognition. Unlike other biometric technologies, including fingerprint recognition, facial recognition, iris recognition, hand geometry recognition, voice recognition, keystroke recognition, and signature recognition, retinal recognition is not widely deployed in commercial applications.

### The anatomy and the uniqueness of the retina

When talking about the eye, especially in relation to biometrics, the iris and the retina are often confused. While they may both be categorised as 'eye biometrics', their respective functions are completely different. The iris is the coloured region between the pupil and the white of the eye (also known as the sclera). The primary purpose of the iris is to dilate and constrict the size of the pupil. In this sense, the iris is analogous with the aperture of a camera.

It is said that the retina "is to the eye as film is to a camera."<sup>1</sup> The retina consists of multiple layers of sensory tissue and millions of photoreceptors whose function is to transform light rays into electrical impulses. These impulses subsequently travel to the brain via the optic nerve, where they are converted to images. Two distinct types of photoreceptors exist within the retina: the rods and the cones. While the cones (of which each eye contains approximately 6 million) help us to see different colours, the rods (which number 125 million per eye) facilitate night and peripheral vision. It is the blood vessel pattern in the retina that forms the foundation for retinal recognition as a science and technology.

Figure 1 shows a side view of the eye - the iris is located

in the front of the eye, while the retina is located at the back. Because of its position within the eye, the retina is not exposed to the external environment. As a biometric, it is therefore very stable.

Figure 2 shows a front view of the blood vessel pattern within the retina. The red lines represent the actual blood vessels; the yellow section indicates the position of the optic disc (the place where the optic nerve joins the retina). It is from here that information is transmitted to and received from the brain. The circle in the diagram indicates the area that is typically captured by a retinal scanning device. It contains a unique pattern of blood vessels.

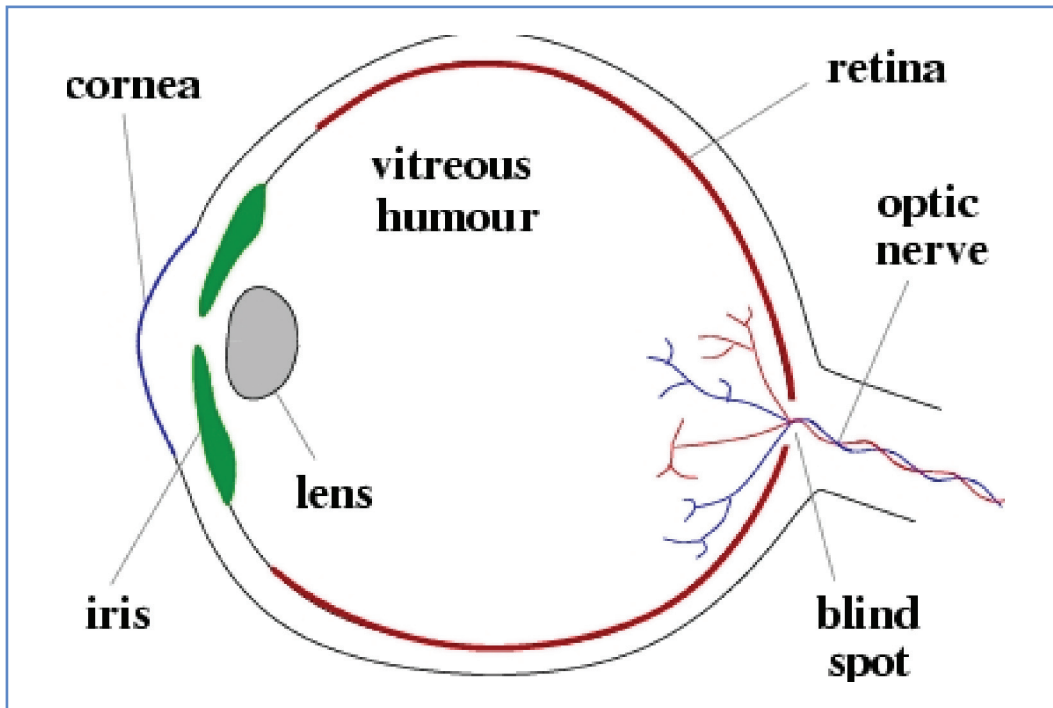
There are two famous studies that have confirmed the uniqueness of the blood vessel pattern found in the retina. The first was published by Dr Carleton Simon and Dr Isodore Goldstein in 1935, and describes how every retina contains a unique blood vessel pattern. In a later paper, they even suggest using photographs of these patterns as a means of identification. The second study was conducted in the 1950s by Dr Paul Tower. He discovered that - even among identical twins - the blood vessel patterns of the retina are unique and different.

### The technology behind retinal recognition

The first company to become involved in the research, development and manufacture of retinal scanning devices was EyeDentify Inc. The company was established in 1976 and its first retina capturing devices were known as 'fundus cameras'. While intended for use by ophthalmologists, modified versions of the camera were used to obtain retina images. The device had several shortcomings, however. First, the



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**Figure 1**  
Side view of the eye.

equipment was considered very expensive and difficult to operate. Second, the light used to illuminate the retina was considered too bright and too discomforting for the user.

Further research and development yielded the first true prototype scanning device, which was unveiled in 1981. The device used infrared light to illuminate the blood vessel pattern of the retina. The advantage of infrared light is that the blood vessel pattern in the retina can ‘absorb’ such light much faster than other parts of the eye tissue. The reflected light is subsequently captured by the scanning device for processing. In addition to a scanner, several algorithms were developed for the extraction of unique features. Further research and development gave birth to the first true retinal scanning device to reach the market: the EyeDentification System 7.5. The device utilised a complex system of scanning optics, mirrors, and targeting systems to capture the blood vessel pattern of the retina. Ongoing development resulted in devices with much simpler designs. Later scanners consisted of integrated retinal scanning optics, which sharply reduced manufacturing costs (compared to the EyeDentification System 7.5.).

The last retinal scanner to be manufactured by EyeDentify was the ICAM 2001, a device capable of storing up to 3,000 templates and 3,300 transactions. The product was eventually withdrawn from the market on account of its price as well as user concerns. As far as the author is aware, only a single company is currently in the process of creating a retinal scanning device: Retinal Technologies, LLC. It is believed that the

company is working on a prototype device that will be much easier to implement in commercial applications. It will also be much more user friendly. Based on a scientific study whitepaper written by Retinal Technologies, it appears that the methods used for testing their device reveal “huge potential.”<sup>2</sup>

The overall retinal scanning process may be broken down into three sub-processes<sup>3</sup>:

1. Image/signal acquisition and processing - this sub-process involves capturing an image of the retina and converting it to a digital format.
2. Matching: a computer system is used to verify and identify the user (as is the case with the other biometric technologies reviewed in previous articles).
3. Representation: the unique features of the retina are presented as a template.

The process for enrolling and verifying/identifying a retinal scan is the same as the process applied to other biometric technologies (acquisition and processing of images; unique feature extraction; template creation). The image acquisition and processing phase is the most complicated. The speed and easy with which this sub-process may be completed largely depends on user cooperation. To obtain a scan, the user must position his/her eye very close to the lens. To safeguard the quality of the captured image, the user must also remain perfectly still at this point. Moreover, glasses must be removed to avoid signal interference (after all, lenses are designed to reflect). On looking into the

scanner, the user sees a green light against a white background. Once the scanner is activated, the green light moves in a complete circle (360 degrees). The blood vessel pattern of the retina is captured during this process. Generally speaking, three to five images are captured at this stage. Depending on the level of user cooperation, the capturing phase can take as long as one minute. This is a very long time compared to other biometric techniques.

The next stage involves data extraction. One very considerable advantage of retinal recognition becomes evident at this stage. As genetic factors do not dictate the pattern of the blood vessels, the retina contains a diversity of unique features. This allows up to 400 unique data points to be obtained from the retina. For other biometrics, such as fingerprints, only 30-40 data points (the minutiae) are available.

During the third and final stage of the process, the unique retina pattern is converted to an enrolment template. At only 96 bytes, the retina template is considered one of the smallest biometric templates.

### Causes of problems (errors) and biometric performance standards

As is the case with other biometric technologies, the performance of the retinal scanning device may be affected by a number of variables, which could prevent an accurate scan from being captured. Poor quality scans may be attributable to:

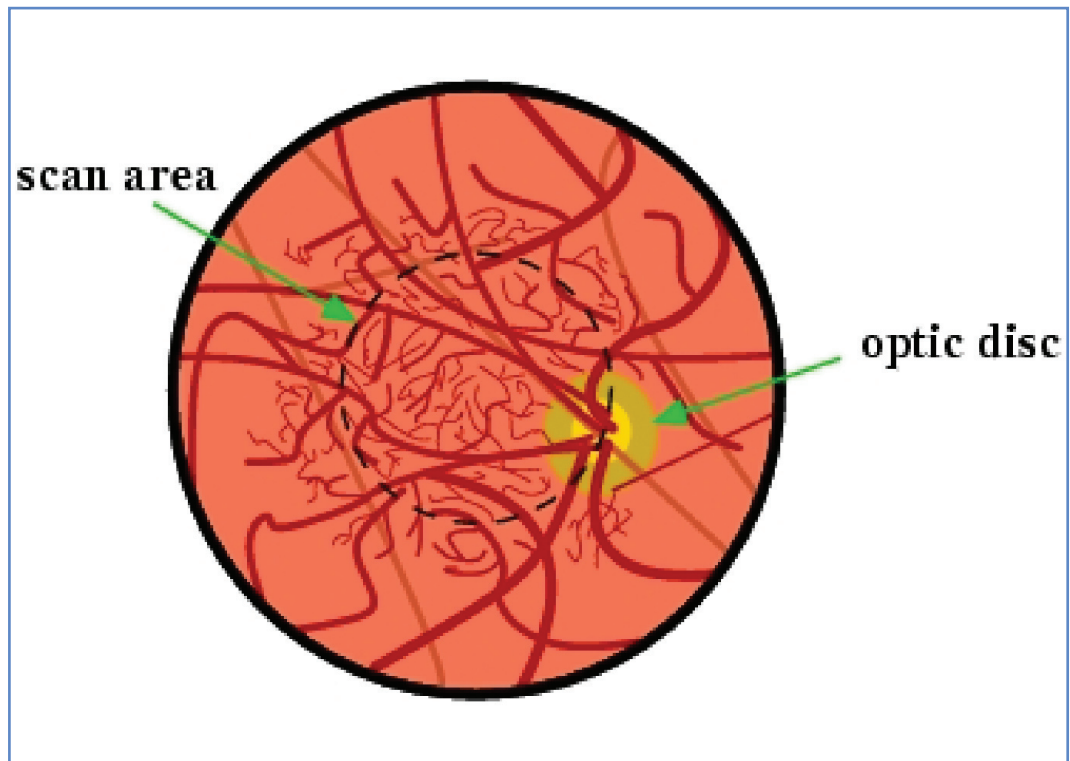
1. Lack of cooperation on the part of the user - as indicated, the user must remain very still throughout the entire process, especially when the image is being acquired. Any movement can seriously affect lens alignment.
2. The distance between the eye and the lens is incorrect and/or fluctuates - for a high quality scan to be captured, the user must place his or her eye in very close proximity to the lens. In this sense, iris scanning technology is much more user friendly; a quality scan can be captured at a distance of up to three feet from the lens.
3. A dirty lens on the retinal scanning device. This will obviously interfere with the scanning process.
4. Other types of light interference from an external source.
5. The size of the user's pupil. A small pupil reduces the amount of light that travels to (and from) the retina. This problem is exacerbated if the pupil constricts as a result of bright lighting conditions, which can result in a higher False Reject rate.

All biometric technologies are rated against a set of performance standards. As far as retinal recognition is concerned, there are two performance standards: the False Reject Rate, and the Ability To Verify Rate. Both are described below.

#### **False Reject Rate (also known as Type 1 Errors)**

Describes the probability of a legitimate user being denied authorisation by the retinal scanning system.

**Figure 2**  
Front view of the blood vessel pattern within the retina.



Retinal recognition is most affected by the False Reject Rate. This is because the factors described above have a tangible impact on the quality of the retinal scan, causing a legitimate user to be rejected.

#### **Ability to Verify Rate**

Describes the probability of an entire user group being verified on a given day. For retinal recognition, the relevant percentage has been as low as 85%. This is primarily attributable to user-related concerns and the need to place one's eye in very close proximity to the scanner lens.

The strengths and weaknesses of retinal recognition just like all other biometric technologies, retinal recognition has its own unique strengths and weaknesses. The strengths may be summed up as follows:

1. The blood vessel pattern of the retina rarely changes during a person's life (unless he or she is afflicted by an eye disease such as glaucoma, cataracts, etc).
2. The size of the actual template is only 96 bytes, which is very small by any standards. In turn, verification and identification processing times are much shorter than they are for larger files.
3. The rich, unique structure of the blood vessel pattern of the retina allows up to 400 data points to be created.
4. As the retina is located inside the eye, it is not exposed to (threats posed by) the external environment. For other biometrics, such as fingerprints, hand geometry, etc., the opposite holds true.

The most relevant weaknesses of retinal recognition are:

1. The public perceives retinal scanning to be a health threat; some people believe that a retinal scan damages the eye.
2. User unease about the need to position the eye in such close proximity of the scanner lens.
3. User motivation: of all biometric technologies, successful retinal scanning demands the highest level of user motivation and patience.
4. Retinal scanning technology cannot accommodate people wearing glasses (which must be removed prior to scanning).
5. At this stage, retinal scanning devices are very expensive to procure and implement.

#### **Retinal recognition applications**

As retinal recognition systems are user invasive as well as expensive to install and maintain, retinal recognition has not been as widely deployed as other biometric technologies (particularly fingerprint recognition, hand

geometry recognition, facial recognition, and, to some extent, iris recognition).

To date, retinal recognition has primarily been used in combination with access control systems at high security facilities. This includes military installations, nuclear facilities, and laboratories. One of the best-documented applications involves the State of Illinois, which used retinal recognition to reduce welfare fraud by identifying welfare recipients (thus preventing multiple benefit payments). This project also made use of fingerprint recognition. Retinal recognition was first introduced in Granite City and East Alton (southern Illinois) towards mid-1996. Once the fingerprint recognition programme had been initiated, the authorities drew up a comparison between fingerprint and retinal recognition, concluding that "retinal scanning is not client or staff friendly and requires considerable time to secure biometric records. Based on these factors, retinal scanning technology is not yet ready for state-wide adaptation to the Illinois welfare department..."<sup>4</sup>. As a result, the use of retinal recognition systems was stopped.

#### **To conclude**

In view of the rich and unique blood vessel patterns in the retina, there is no doubt that retinal recognition is the 'ultimate' biometric. Its high cost and user-related drawbacks have prevented it from making a commercial impact. However, as technology continues to advance, it seems likely that retinal recognition will one day be widely accepted and used.

<sup>1</sup> "Retina Identification", Robert "Buzz" Hill. Article is from the book: "Biometrics: Personal Identification in Networked Society", by Anil Jain, Ruud Bolle, and Sharath Pankati - p.124

<sup>2</sup> "Retinal Identification System: Performance Analysis" Scientific whitepaper provided by Retinal Technologies, LLC

<sup>3</sup> "Retina Identification", Robert "Buzz" Hill. Article is from the book: "Biometrics: Personal Identification in Networked Society", by Anil Jain, Ruud Bolle, and Sharath Pankati - p.126.

<sup>4</sup> [www.dss.state.ct.us/digital/illinois.htm](http://www.dss.state.ct.us/digital/illinois.htm)