



Research on Retinal and Iris Identification Systems

Yesim Ulgen Sonmez¹, Asaf Varol^{2*}

¹ Department of Software Engineering, Technology Faculty, Firat University, Elazığ, Turkey, yesimulgen123@gmail.com

² Corresponding author: Department of Software Engineering, Technology Faculty, Firat University, Elazığ, Turkey,

*CorrespondingAuthor email: varol.asaf@gmail.com

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Abstract

Biometrics is the science that analyzes biological data and also the technology that measures biological data. Biometric systems make identification or identity verification by using measurable, distinctive physical and behavioral properties of humans. The most widely used biometrics techniques rely on finger prints, palm, hand geometry, iris, retina, face, ear shape, vein, signature, hand writing and voice identification of an individual. Iris identification systems and retina identification systems are the most accurate and reliable identifying techniques. Iris is a circular structure surrounding the pupil, which determines eye color. The iris is a very rich tissue and it has a unique texture. This texture is different for each individual and it will stay same throughout their lives. Iris identification systems use the mathematical pattern-identification algorithms and statistical methods on individuals' captured iris images. Retina, similar to iris, is unique for each person and has an unchanging texture throughout the life, except for some side effects of diseases. Retina that is located in the back side of the eye is responsible for vision. The mesh of blood vessels in retina is very complicated and distinctive. In retina identification systems, firstly, infrared light is radiated into the eye and blood vessels create unique reflections of this light. Retina identification is used in many areas from security systems to medical applications. This study examines and presents similarities and differences between two ocular biometric systems which are iris identification systems and retina identification systems. Analysis has also been carried out using the findings of this study.

Key words

Biometrics, Iris identification System, Retina identification Syst

1. INTRODUCTION

Biometric systems work with the principle of examining and identifying some unique physiological and behavioral characteristics of each person. The way the human brain works is taken as the basis of biometric systems. In such systems, there are two phases called identification and verification. In identification phase, data is collected and saved in the database as computer codes (which are digital codes). In the verification phase, the data collected is compared with the data of the person who requests access and a conclusion is reached by the system.

Iris and retina identification systems are among ocular identification systems. However, they do have different structures and they are different biometric systems. Iris and retina tissues are unique and distinctive for each and every human being. The structure of iris does not change from birth to death. Retina tissue also does not change, however it is affected by some diseases like diabetes, high blood pressure, MS and leukemia. Thus, iris and retina identification systems are the highest grade biometric systems in their field with the properties of uniqueness, accuracy, universality and permanence. The rich texture of iris is essential for the iris identification systems. The shape of capillaries is taken into account for retina identification systems.

This study examines and presents similarities and differences between two ocular biometric systems which are iris identification systems and retina identification systems. Analysis has also been carried out using the findings of this study.

1.1. Biometric System Characteristics and Criteria

There are unique characteristics used in biometric systems which are unique for each and every human being. These can be finger prints, palm structure, hand shape, vein patterns, finger joint prints in hands, ear shape, teeth, tongue print in face area, retina, iris and sclera in the eyes, and as with biological properties go, DNA, bodily scent, heart sound, or behavioral features such as voice, signature, keystroke patterns and style of walking. [1].

Biometric traits must have some criteria. These criteria can be listed as follows [1, 2].

- Universality: Every person should have that particular trait [1-5]. It should exist in every individual.
- Distinctiveness/Uniqueness: The trait should be effectively different for each person [1-5].
- Permanence: The characteristic should not change as time goes by, it should permanently stay the way it is [1-5].
- Collectability: The trait which will be measured should be easily acquired by suitable devices. [1-5].
- Measurability: The quantitative measurability of the trait.
- Performance: Performance is accuracy and speed, and also robustness of the technology used [1-4]. It is the relative success of defining the biometric trait [1].
- Acceptability: The approval rating of the technology used [1-5]. This can be defined as agreeable of acquisition and assessment of the biometric characteristic [1-5].
- Circumvention: The ease of using a substitute [1-4]. The biometric system can be fooled easily by unauthorized persons.
- If the human trait carries the permanence, universality, uniqueness, collectability criteria, it can be used for querying within a biometric system. If a system uses such a biometric trait and appropriate and robust technological equipment, it can be accepted as a reliable and powerful biometric system.

Table 1 shows the comparison of iris and retinal biometrics, according to biometric trait criteria, under suitable conditions [1, 2]. In the table, H means "high", L means "low" and M means mediocre.

Table 1. Comparison of iris and retina characteristics [1, 2, 6].

| | Uniqueness | Universality | Permanence | Measurability | Performance | Acceptability | Circumvention |
|--------|------------|--------------|------------|---------------|-------------|---------------|---------------|
| Iris | H | H | H | M | H | L | L |
| Retina | H | H | M | L | H | L | L |

The measurements used in biometric systems are called biometric measurements. There are international standards for the use of these systems in passwords. These standards are set by INCITS, International Committee for Information Technology Standards [2, 7]. Thanks to these standards, any person with a bank account who can reach his account with iris or palm identification systems, can reach his bank account in his home country from anywhere around the world and make a transaction [2].

1.2. Comparison of Iris and Retinal Biometrics

In table 2, ease of use, possible problems, performance and security requirements of iris and retinal biometric systems under appropriate conditions have been compared.

Retina identification systems are systems with high accuracy and speed; however, because they need focus of the camera, they are not widely used biometrics [1, 4, 8].

Table 2. Comparison of iris and retina biometric systems [1, 8].

| Biometric Trait | Ease of Use | Problems | Accuracy | Security Requirements |
|-----------------|-------------|----------|-----------|-----------------------|
| Retina | Low | Glasses | Very high | High |
| Iris | Medium | Light | Very high | Very high |

1.3. Areas in Which Retina and Iris Biometrics are used

In table 3, the most common usage areas for iris and retinal biometrics have been listed. The most widely used biometric traits that are used for border security application are iris and retina. In ID cards and passports however, iris is used more in comparison to retina.

Table 3. Fields of application for iris and retinal biometrics [1, 9].

| | Iris | Retina | Sclera |
|------------------------------|------|--------|--------|
| Border Security | x | x | |
| Forensics | | | |
| Identification of Criminals | x | x | |
| ID Cards | x | | |
| Passports | x | | |
| Computer Logon Processes | x | | x |
| Access Control | x | x | x |
| Electronic Trade | x | | x |
| Smart Phones | | | |
| Imaging Systems | x | | |
| Watching Videos | | | |
| Missing Child Identification | x | | |
| Crowd Tracking | | | |
| Electronic Banking | | | |

2. OCULAR BIOMETRICS

Because of relatively more accurate and permanent characteristics of ocular biometric traits, many different approaches have been developed regarding ocular identification [1, 9]. The most important biometric traits in the ocular area are iris, sclera and retina. In iris based biometric systems, identification is done by benefiting from color, shape and the properties of iris tissue. Besides the distinctive property of iris, as these character based systems are relatively expensive and prone to attacks, they are not very widely used [1, 10].

In retina based biometric systems, the attributes of blood vessels which filter the light and optical field in retina are used as the distinctive traits [1, 9]. As the retina identification systems are expensive and it is rather difficult to obtain the data, they are not also widely used.

The sclera of the eye consists of blood vessels. The particular patterns of these blood vessels are used in sclera based biometric systems. [1, 9].

2.1. The Structure of the Eye and Eyesight

Eyes are very special and important organs which take in the light that is originated from the sun, and reflected from objects. The light that is visible to human eye is called visible light. It is the light in between wavelengths of 400 and 700 nanometers. Human eyes cannot perceive X rays, ultraviolet rays and infrared rays [11, 12]. Eye consists of two types of structures, one for sight, and others for the protection of these structures. The protective structures are the eyelids, eyebrows, eyelashes, lacrimal glands, and the muscles that connect the

eyes to their circular orbits and provide movement [11]. The structure of a human eye is made up of three layers. These layers are the sclera on the outer layer, choroid in the middle and retina in the inner layer [11].

Sclera is the white part of the eyeball. Sclera is a structure that surrounds and protects the eye. It becomes the transparent cornea on the front side of the eye and lets the light enter.

Choroid is beneath the sclera. Its exact place in the eye is shown in figure 1. It consists of blood vessels that feed the eye. It also absorbs excess light and prevents damage to the eye. Choroid gets thicker in the front side of the eye and becomes the round and colorful structure called iris [11].

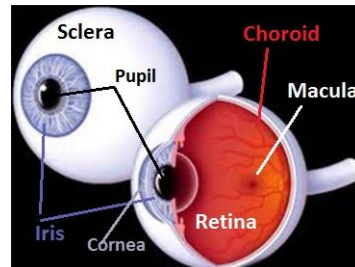


Figure 1. Anatomy of the eye [39]

Iris can be in different colors according to the color material that it possesses. Iris color can be black, brown, blue, green or hazel.

In the middle of iris is the pupil, which is a gap. The light enters the eye through this gap and goes to the back of the eye, to retina. As shown in figure 2, iris either enlarges or shrinks the pupil, according to the amount of light entering the eye. Thus, pupils constrict in bright light and they dilate in darkness.

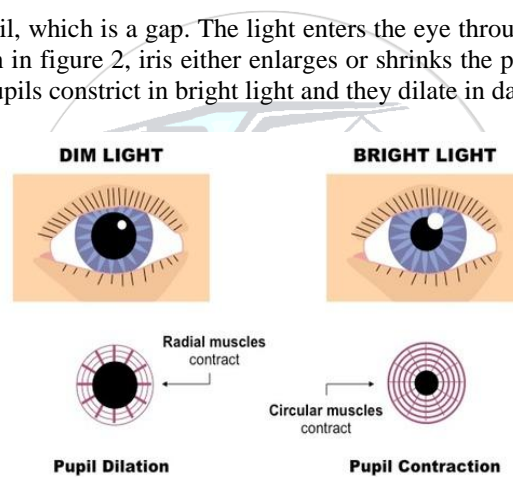


Figure 2. Constriction and dilation of the pupils [40].

Retina is the inner layer of the eye. It receives colors and impulses and provides vision. As there are networks of nerve endings in this layer, it is called the retina [11].

2.2. The phases in which the vision is realized

Vision starts with the rays of light coming from the sun which are reflected from the objects to come to our eyes. Any ray of light reflected from an object, gets refracted by the cornea and passes through the pupils and reaches to the lens [11].

The light that reached to the lens is refracted once again and passes on to vitreous body and reaches to the retina. The rays of light that reached the retina create electrical pulses on optic nerves. These electrical impulses allow the formation of a reverse image in the macula [11]. Optic nerve transmits this reverse image to the brain. The part of the brain which manages sight rotates the image and, thus seeing occurs.

Figure 3 shows how seeing works, how the light is refracted, where the vision is created, and how it is transmitted to the brain. The role of iris in seeing is to control the size of pupils and adjust the amount of light entering into the eye [13].

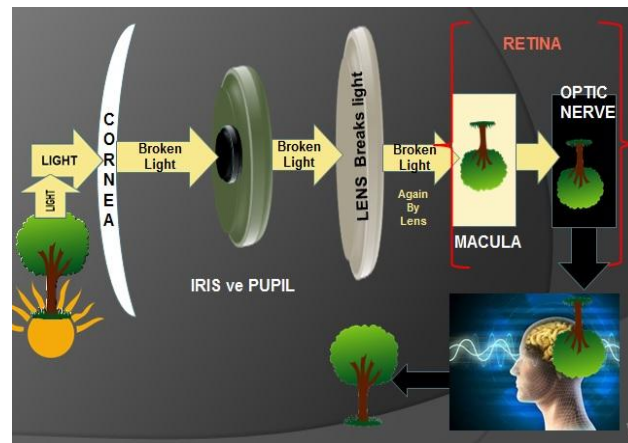


Figure 3. The phases of seeing

3. IRIS IDENTIFICATION SYSTEMS

Iris identification system is one of the most accurate and reliable biometric systems because it uses the unique and unchanging structure of iris. It was first introduced by John Daugman in 1993. J. Daugman, in 1994, introduced a prototype that delivers excellent results over databases with many different images and developed a human identification system based on iris analysis [13].

Iris identification is a highly reliable biometric method used for identification. The iris pattern of the person whose iris is scanned is mapped and converted into a digital code in various ways. This digital iris code is matched with the other ones in the database in order to make identification [14].

3.1. The Unique Structure of Iris

In 1985, Leonard Flom and Aran Safir have proven that iris pattern of each and every human being is different [14]. This part is also the part which gives the eye its color. The color of iris depends on cell density and pigment concentration. For example, brown eyes have more cell density and pigment count compared to blue eyes. The structure of iris is not hereditary, however its color is.

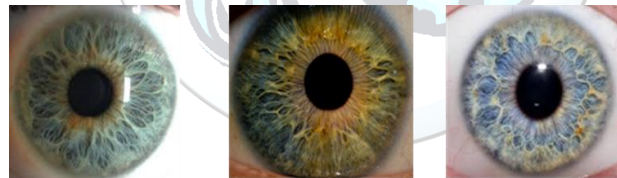


Figure 4. Different iris structures

The features related to the unique structure of iris which enables it to be a biometric trait are as follows;

- The structure of each person's irises is unique. Even though DNA structures in twins are the same, their irises are still different.
- There are even differences between the right and left irises.
- Iris is much less affected by genetic factors.
- Iris structure does not change with genetic diseases.
- Race, gender or skin color does not affect the characteristics of the iris.
- It is an internal organ which can be seen and measures externally.
- The structure of iris does not change. Due to its permanence, it is a secure biometric trait.
- Eye is the organ which loses its viability the quickest after death.

Figure 4 illustrates different iris tissues. Iris possesses the tissue properties of sclera and retina [13]. In biometric systems, this rich tissue's structure is converted into digital codes using various methods [14].

For a clear visibility of the iris tissue, the eye should be photographed using 750 nm infrared light. Because with visible daylight (400-700 nm), these tissues can't be seen clearly [14].

3.2. The Way the Iris Identification Systems Work

3.2.1. Photographing the Iris

There are stages of iris identification systems. In the first stage, digital photographs of the person who requests access to the system are taken using video cameras. This stage requires the person to willingly look at the camera. This biometric system is not intrusive as there is no contact with the eye by the camera, thus it is healthy. This way of it increases its adoption level by the people.

3.2.2. Localization – Locating the Iris and the Pupil

The captured image is processed using visual processing methods. Meanwhile, iris and pupil is distinguished in the image taken and the remaining parts are removed from the image. The purpose for doing that is to separate eyebrows, eyelashes etc. from the iris in order to create a code and make a healthy analysis. At this stage, the center of the pupil is also determined [13]. Various edge detection methods are applied in this stage.

3.2.3. Segmentation

At this stage, as shown in Figure 5, the circular edge between the iris and the pupil, and the circular edge between the iris and the sclera is determined.



Figure 5. Determining circular borders and noise [13, 41]

The noise on the iris image is removed using a variety of image processing techniques. The noises over the iris image are factors like eyebrows, eyelashes, eyelids and light reflections etc. The removal of such factors from the image is called noise detection [13, 45, 46]. In figure 5, the pupil, iris and sclera is separated from each other using circular edge detection methods.

3.2.3.1. John Daugman Segmentation Method

Daugman used circular edge detection methods to determine the borders of iris, pupil and sclera. Especially to separate sclera from the iris, he used maximum gradient integrodifferential equation in iris images [13].

$$\max_{r, x_0, y_0} \left| \frac{\partial}{\partial r} G(r) * \oint_{r, x_0, y_0} \frac{I(x, y)}{2\pi r} ds \right| \quad (1)$$

$$G(r) = \left(\frac{1}{\sqrt{2\pi}\sigma} \right) e^{-\left(\frac{r-r_0}{2\sigma^2} \right)^2} \quad (2)$$

$G(r)$, is the radial Gaussian function. $I(x, y)$ is the input iris image. The first equation looks for the maximum value with fuzzy partial derivative for increasing radius and $(0, 0)$ x_0, y_0 central coordinate. This method is also called active contour fitting [13, 15].

3.2.3.2. John Daugman Polar Conversion Method

The system generates a coordinate system on the localized iris image. The center of the coordinate system is the center of the circular pupillary boundary. Figure 6 shows the cartesian form of the iris image [13, 41].

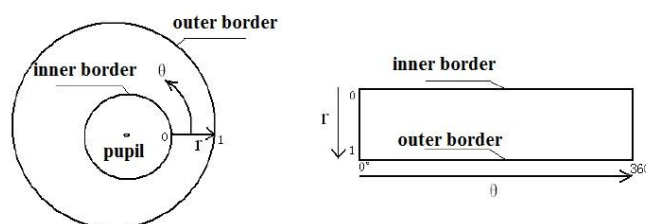


Figure 6. Cartesian form of the iris image, normalization and polar form [41, 42, 46].

3.2.4. Normalization - Polar Transformation

At this stage polar transformation is applied to the image and it is converted into dimensionless form polar from cartesian form. Daugman used radial scaling method for polar conversion [13, 46].

$$x(r, \theta) = (1 - r)x_p(\theta) + rx_1(\theta) \quad (3)$$

$$y(r, \theta) = (1 - r)y_p(\theta) + ry_1(\theta) \quad (4)$$

As shown in figure 6, the image is converted from (x, y) form into polar (r, θ) form, using image radial scaling and polar transformation [13]. Figure 7 shows (a) the image of iris area, (b) the iris image after the application of polar transformation and normalization. Daugman's polar transformation method is called Rubber Sheet model [42].

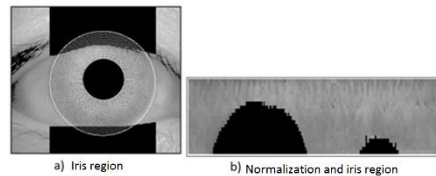


Figure 7. Normalized iris image [46].

In this stage, in order to compose a clearer iris code, histogram equalization and noise reduction methods are applied once again on the polar image.

3.2.5. Demodulation - Formation of Iris Code

After the normalization, feature vector (digital code) of the polar iris image is created during the demodulation stage. Pattern identification methods are used for image identification. In the first iris identification system, the digital code of the image is reduced to a size between 256 and 512 bytes, using a function called "2D Gabor wavelet transform" [13,16]. The created iris template in other words iris feature vector is matched with other iris templates in a huge database, for the identification and verification. During all these processes, the iris code is password protected and it is impossible to use them in any other way [16].

At this stage, feature extraction is performed using Gabor wavelet filter. Gabor wavelet filter is applied on the normalized image and a binary iris code like the one seen in figure 8 is created, which is in a fixed size and universal format.



Figure 8. Binary iris code [13, 44, 45].

In the field of iris identification, there are many different feature extraction methods in literature, for converting iris images into digital codes. Some of these methods are as follows [13];

- 1-D Gabor Wavelet Transform
- 2-D Gabor Wavelet Transform
- Correlation Filter
- Haar wavelet transform
- Dyadic wavelet transform
- Discrete Cosine transform
- Log Gabor wavelet transform
- Zero-Crossing wavelet transform

3.2.6. Iris Identification Methods According to Iris Encoding

Iris identification Methods according to Iris Encoding are separated into 4 different classes [13]. These classes are as follows;

- Phase based methods [17]
- Zero pass method [18, 19]
- Tissue analysis method [19, 20, 21,22]
- Density gradient analysis [23]

3.2.7. Comparison of Iris Codes

After the iris image of the person who demands access to the system passes the segmentation, normalization and demodulation processes, it is matched with the iris templates in the database and then identification is done. For this comparison, different methods and classifiers are used.

The comparison method of Daugman was Hamming Distance [13]. Hamming distance is the comparison of two binary codes XOR and AND. It calculates the difference between the bits of two iris codes [13, 43, 45].

$$HD = \frac{(IrisCodeA \oplus IrisCodeB) \cap MaskA \cap MaskB}{MaskA \cap MaskB} \quad (5)$$

Normalized Hamming distance

$$HD = \frac{1}{2048} \sum_{j=1}^{2,048} A_j \oplus B_j \quad (6)$$

System makes matching according to the results of the Hamming distance results. It reaches to yes or no decisions. Figure 9 shows the matching in between three iris samples. Hamming distances have been calculated. The iris with the smallest value of distance matches with the code [24]. It produces a "yes" result. Without any match, a "no" answer is produced.

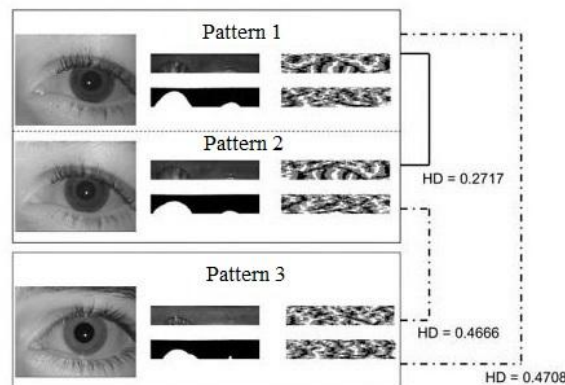


Figure 9. Hamming distance [24].

When the studies in the literature are examined, the classifiers used for the comparison of iris codes are as follows [13];

- Hamming Distance
- Euclid Distance
- Support Vector Machine (SVM)
- Artificial Neural Networks (NN)
- Nearest Neighbor Clustering (kNN)
- Self-Organized Feature Maps (SOM)
- Vector Quantization Learning (LVQ)
- Bayes Classifier

The iris codes derived from the iris images of a living eye are matched with another iris code which was previously saved in the database, within a few seconds. If there is any damaged bit on the iris code, the system detects it and only matches the valid ones [16].

4. IRIS IDENTIFICATION STUDIES IN LITERATURE

Wildes [21, 25, 26] used different methods from what John Daugman used for iris identification. Wildes first used a histogram based approach for the detection of circular edges of the iris and pupil, then, he used Hough transform [26]. Eyelids were identified as parabolic arcs.

$$H(x_0, y_0, r) = \sum_{j=1}^n h(x_j, y_j, x_c, y_c, r) \quad (7)$$

$$h(x_j, y_j, x_0, y_0, r) = \begin{cases} 1, & \text{if } g(x_j, y_j, x_0, y_0, r) \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

$$g(x_j, y_j, x_0, y_0, r) = (x_j - x_0)^2 + (y_j - y_0)^2 - r^2 \quad (9)$$

Wildes uses image saving technique for the scaling and rotation.

$$\int_x \int_y (I_d(x, y) - I_a(x - u, y - v))^2 dx dy \quad (10)$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} x \\ y \end{pmatrix} - sR(\theta) \begin{pmatrix} x \\ y \end{pmatrix} \quad (11)$$

Matching function that minimizes the similarity transformation which transforms (x, y) coordinates into (x', y') is used [21, 25]. Instead of capturing the spatial details of the iris, isotropic band-pass derived with Laplacian of Gaussian is made. For the matching in between the obtained pattern and the patterns in the database, normalized correlation is used.

In the literature, in different stages of iris identification, there are studies carried out for the systems to perform better [13]. These are as follows;

- Systems have been developed which use iris code as biometric secret key. These keys were more secure than crypto-graph based keys [27].
- In order to improve real time localization (iris and pupil separation), methods which are based on particle swarm optimization have been developed [28].
- 2D Haar wavelet transform was used, which separates iris images into 4 different phases and this 4 phases of high frequency information was quantized in 87 bits code form. For classification, vector quantized learning (LVQ) has been applied [29]. In another study, iris identification systems have been produced which are based on the zero pass of wavelet transform [30].
- Iris identification systems combining wavelet transform and support vector machines have been developed. Support vector machine wavelet transform method reduced the error rates.

Methods using support vector machines have given much better results compared to methods using feed-forward artificial neural networks, nearest neighbor clustering, Hamming and Mahalanobis distance classifiers [13].

As a result of the research, it's been determined that Haar wavelet transform does better feature extraction compared to Gabor filter [20]. Image 10 shows the iris code with applied 5-D Haar wavelet transform. Haar WT is used in visible light photos.



Figure 10. Iris code with Haar wavelet transform applied [31].

5. RETINAL IDENTIFICATION SYSTEMS

Retinal identification systems are biometric systems which convert the retinal pattern which consists of capillaries, into a digital code.

5.1. The Unique Structure of the Retina

Retina is located behind the eyeball and is the most inner layer of the layers of the eye. It is rich in capillaries. These blood vessels absorb the excess light and protect the eye from damages. While working on ocular diseases in 1935, Dr. Carleton Simon and Dr. Isodure Goldstein found that each eye has a unique blood vessel structure [33]. Later on, it's also seen that although twins have the same genetic code, have different retinal patterns [34].

After the discovery that the retinal structure is unique and different for each and every human being, and is also universal, it's been understood that it could be used for identification and studies for a retinal identification system has been started. Retina can be affected by diseases like diabetes, high blood pressure, blood and cardio vascular diseases. This diminishes its reliability as a biometric system a little bit. In figure 11, (a) original photo of the retina, (b) blood vessel network of retina.

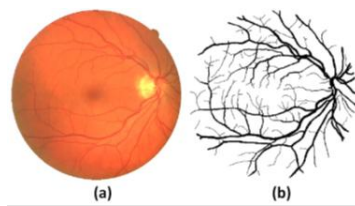


Figure 11. (a) Original retinal image (b) Blood vessels [34, 35].

5.2. Working Methods of Iris Identification Systems

Retinal identification system consists of the following stages: obtaining retinal image, segmentation, blood vascular pattern extraction, feature extraction and filtering, finally biometric pattern matching. The flowchart of retinal identification is given in figure 12.

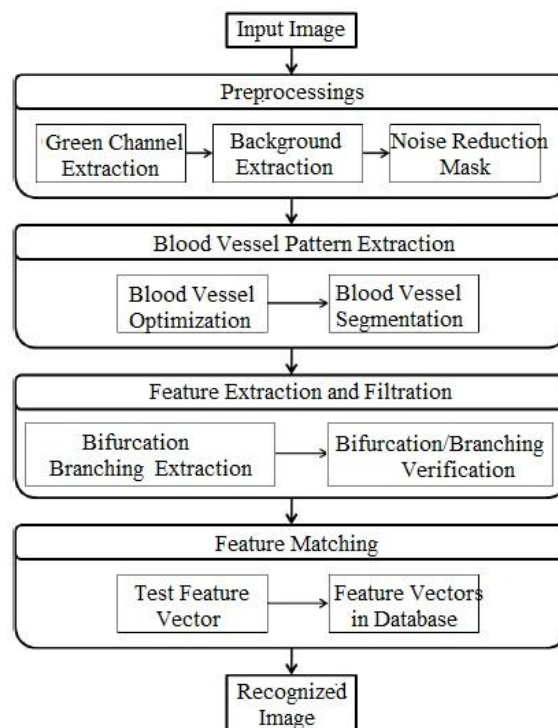


Figure 12. Flowchart of retinal identification system [32].

5.2.1. Obtaining the Retinal Image - Acquisition

The eye of the person who wants access to the system is photographed from close proximity. As the retina is behind the eye, the person has to stay close to the camera. The infrared ray of light is shone to the eye. This light passes the lens and follows the retinal path and reaches the capillaries in the retina. Meanwhile, the capillaries undergo changes as the light reaches them. They take different shapes and forms. These characteristic shapes are reflected to a video camera. System obtains the image from this reflection.

5.2.2. Preprocessing, Segmentation and Optimization

There are green, red and blue levels in digital photos. A photo can be viewed in different levels. Green channel has a higher density compared to red and blue channels. Thus green channel is extracted from the photo. The green channel is located with the following mathematical formula.

$$G = \frac{G}{R+G+B} \quad (12)$$

R means the red channel, G means the green channel and B means the blue channel [38]. In figure 13, retinal images have been given according to the techniques applied in the preprocessing stage.

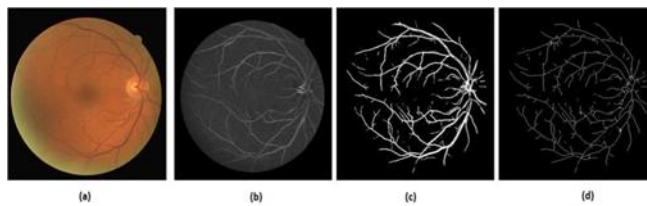


Figure 13. (a) green channel image (b) optimized capillaries (c) Segmented image (d) Refined capillaries [34, 35].

Preprocessing stage includes the detection of noise and separation of background from the retinal image and to highlight the blood vessel pattern. The correction of retinal identification depends on the extraction of the features of capillaries. The preprocessing includes the following actions;

- First, optimization of the image is done using wavelet transform in order to extract capillary pattern.
- A multi layered thresholding is applied on the optimized retinal image.
- Wavelet transform method is used for feature extraction. The used transform methods are as follows [34].
- Constant wavelet transform (CWT) $T\psi (b, \theta, a)$
- Fourier wavelet transform (FWT)
- 2-D Gabor wavelet transform

With Gabor wavelet transform, optimized vascular pattern can be obtained [34].

5.2.3. Feature Extraction and Bifurcation

Bifurcation means branching. The main features of vascular patterns are vascular endings and branching points [35]. The system uses the crossing number method which is shown in figure 14, for the extraction of the vascular endings and branching [35]. Figure 15 shows the vascular features and branching which are obtained using this method.

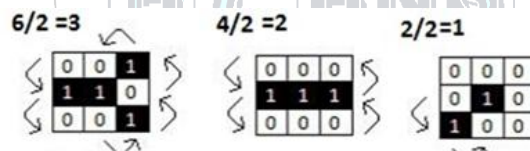


Figure 14. Crossing number method [36].

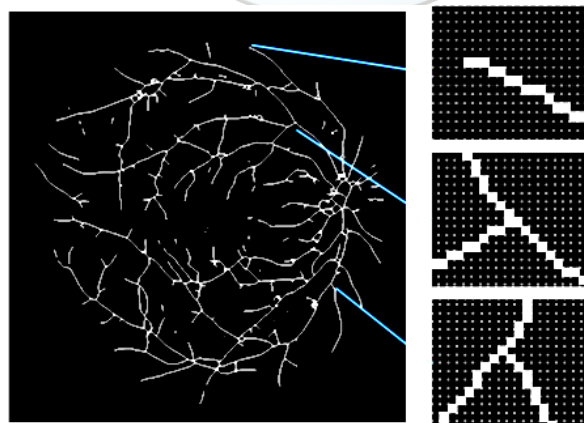


Figure 15. Vascular features, endings and bifurcation [34].

The mathematical expression of this method:

$$C(p) = \frac{1}{2} \sum_{i=1}^8 |g(p_{i \bmod 8}) - g(p_{i-1})| \tag{13}$$

g is the refined retinal image and p represents each vascular pixel. Pixels between p_0 and p_7 are the pixels in clock wise which define the 8 neighboring of p and $g(p)$ is the pixel value [34]. For vascular pixels $g(p) = 1$,

for others $g(p) = 0$. $C(p) = 3$ and $C(p) = 1$ are branching and vascular endings. Feature spots obtained with this algorithm are the correct ones. In order to determine the wrong spots, 9x9 windowing method is used. Figure 16 shows the wrong spots like blind spots, breaks and short blood vessels.

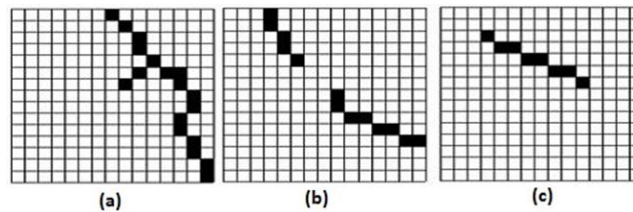


Figure 16. Wrong spots, (a) blind spots, (b) breaks, (c) short Blood vessels [36].

While obtaining the retinal vascular patterns, the purpose is to find the correct branching. After the blind spots, breaks and short blood vessels are found using windowing technique, these are eliminated [36]. Thus, correct endings and branching feature spots can be determined.

5.2.4. Comparison of Vascular Patterns

This is the identification phase. The retinal image taken from the person who wants access is processed using various processing, recognition etc. methods and feature vector (digital code) is generated for the retina. This digital template is matched with other retinal templates in the big database. This comparison can be made using various methods. These methods are as follows;

- Mahalanobis distance
- Vascular pattern correlation
- Matching which use branching spots.

6. PERFORMANCE CRITERIA OF BIOMETRIC SYSTEMS

Performance is an important concept for computerized systems. Any computerized system should operate fast and accurate. The most important performance criteria in biometric systems are total processing time, false acceptance rate (FAR) and false rejection rate (FRR) [2, 37, 45].

The total processing time is the time elapsed between the person's request to access, and the time the access is given. This should take 1-2 seconds in a good system [2, 37]. False acceptance rate is the possibility of access being granted for an unauthorized person, with a faulty decision. False rejection rate is the possibility of access not being granted for an authorized person. The aim for all biometric systems is to reduce both FARs and FRRs below 1%. [2, 37, 45].

7. RESULTS

In this study, different iris and retinal identification methods have been examined, and the similarities and differences of these systems have been identified. It's been seen that these systems are much more reliable, accurate and fast, compared to other biometric systems available. However, their high cost prevents them to be widely adopted.

The similarities between iris and retinal identification can be listed as follows;

- False acceptance rate is low in both.
- False rejection rate is very low, almost 0.
- Highly reliable, because the iris or retinal patterns are unique for everybody.
- Identification is very fast in both.

The differences between iris and retinal identification can be listed as follows;

- The accuracy of retinal scanning can be affected by various diseases, however, the rich texture of the iris is fixed for life and immutable.
- Iris scanning is not different from a normal photo shoot, shots are taken from a short distance. Retinal scanning requires the person to be much more close to the camera.
- Iris is an internal organ which can be seen externally, but retina is on the back of the eye. Therefore, photographs are taken from different distances.
- Iris scanning is more commercially accepted than retinal scans. Retinal scanning is considered to be harmful.

Retina and iris can be used in cryptography with their unique structures. With smart cards that carry both iris and retinal codes, both users and the system owners or institutions can have a more security.

When the properties of retinal and iris identification are analyzed, it is expected that these two systems can perform better compared to other biometric based systems like finger print, face or vascular identification systems. Apart from that, it's also been understood that with a combination of iris and retinal pattern prototype can be one of the most secure identification systems available.

REFERENCES

- [1]. Turhan C., Ceyhan, E., Sağıroğlu Ş., Biyometrik Sistemlerde Güvenlik Üzerine Bir İnceleme, www.iscturkey.org, access: 03.03.2016.
- [2]. Yalçın, N., Gürbüz, F., 2015. Biyometrik Güvenlik Sistemlerinin İncelenmesi, Düzce Üniversitesi Bilim ve Teknoloji Dergisi, cilt 3, no. 2, pp.
- [3]. Elumalai, K., Kannan, M., 2011. Multimodal Authentication For High End Security, International Journal on Computer Science and Engineering (IJCSSE), 3(2), 687-692.
- [4]. Jain, K., Bolle, R., Pankanti, S., 1999. Biometrics: Personal identification in Networked Society, Springer Science and Business Media.
- [5]. Ergen, B., Çalışkan, A., 2011. Biyometrik Sistemler ve El Tabanlı Biyometrik Tanıma Karakteristikleri, 6th International Advanced Technologies Symposium, Elazığ-Türkiye.
- [6]. Jain, A.K., Ross, A., Prabhakar, S., 2004. An Introduction to Biometric identification, IEEE Transaction on Circuits and Systems for Video Technology, vol.14, no.1, pp.4-20.
- [7]. Şamlı, R., Yüksel, M. E., 2009. Biyometrik Güvenlik Sistemleri, Akademik Bilişim, Şanlıurfa-Türkiye.
- [8]. Liu, S., Silverman, M., 2001. A Practical Guide to Biometric Security Technology, IT Professional, vol. 3, no. 1, pp. 27-32.
- [9]. Unar, J., Senga, W., Abbasia, A., 2014. A Review of Biometric Technology Along with Trends and Prospects, Pattern identification, vol. 47, pp.2673-2688.
- [10]. Monrose, F., Rubin, A., 1997. Authentication via Keystroke Dynamics, 4th ACM Conference on Computer and Communications Security, Switzerland, pp. 48-56.
- [11]. http://www.biyolojisisitesi.net/tum%20uniteler/denetleme_ve_duzenleme/gorme_nasil_gercekleisir.html, access: 6.1.2016.
- [12]. Yücel, E. Işık, Renk ve Elektromanyetik Spektrum, http://www.akat.org/sizin_icin/elektromagnetik_tayf.pdf, access: 6.1.2016.
- [13]. Alkoot, Fuad M., 2012. A Review On Advances In Iris identification Methods, International Journal of Computer Engineering Research, vol. 3(1), pp. 1-9, Kuwait.
- [14]. http://www.biltek.tubitak.gov.tr/haberler/tip/s528_5.pdf, access: 6.1.2016.
- [15]. Tasyapi Celebi A., Güllü, Kemal M., Ertürk, S., 2009. Low-complexity Iris identification Using One-bit Transform and Angular Radial Partitioning, 2009 IEEE 17th Signal Processing and Communications Applications Conference.
- [16]. <http://www.ergosis.com.tr/iris-tanima-teknolojisi.html>, access: 6.1.2016.
- [17]. Daugman, J., 2003. Demodulation by Complex-Valued Wavelets for Stochastic Pattern identification, Int. J. Wavelets, Multi-Res. and info. Processing, 1(1): 1-17.
- [18]. Daugman, J., Downing, C., 1995. Demodulation, Predictive Coding and Spatial Vision, J. Opt. Soc. Am. A 12: 641-660.
- [19]. Sanchez-Avila, C., Sanchez-Reillo, R., 2002. Iris-Based Biometric identification Using Dyadic Wavelet Transform, IEEE Aerosp. Electron. Sys. Mag., 17:3-6.
- [20]. Lim, S., Lee, K., Byeon, O., Kim, T., 2001. Efficient Iris identification Through Improvement of Feature Vector and Classifier, ETRI J. 23(2): 1-70
- [21]. Wildes, R., Asmuth, J., Green, G., Hsu, S., Kolczynski, R., Matey, J., McBride, S., 1996. A Machine-Vision System for Iris identification, Mach. Vis. Applic., 9: 1-8.
- [22]. Zhu, Y., Tan, T., Wang, Y., 2000. Biometric Personal identification Based On Iris Patterns, Int. Conf. Pattern identification, II:805-808.
- [23]. Ma, L., 2003. Personal identification Based On Iris identification, Ph.D dissertation, China.
- [24]. Jain, A., Ross, A., Nandakumar, K., Introduction to Biometrics, <https://books.google.com.tr/>, access: 6.1.2016.
- [25]. Wildes, R., 1994. A System for Automated Iris identification, 2nd IEEE Workshop Applicat. Comput. Vision, pp.121-128.
- [26]. Jones, M. J., Guo, G., 2008. Iris Extraction Based on Intensity Gradient and Texture Difference, IEEE Workshop on Applications of Computer Vision Conference.
- [27]. Ziauddin, S., Dailey M., 2010. Robust Iris Verification for Key Management, Pattern identification Letters, 31(9).
- [28]. Perez, C. A., Aravena, C. M., Vallejos, J. I., Estevez, P. A., Held, C. M. 2010. Face and Iris Localization Using Templates Designed by Particle Swarm Optimization, Pattern identification Letters, 31(9): 857-868.
- [29]. Lim, S., Lee, K., Byeon, O., Kim, T., 2001. Efficient Iris identification Through Improvement of Feature Vector and Classifier, ETRI J. 23(2): 1-70.
- [30]. Boles, W., Boashash, B., 1998. A Human identification Technique Using Images of Iris and Wavelet Transform, IEEE Transaction on Signal Processing, 46(4).
- [31]. Murty, P. C., Reddy, E. S., Babu, I. R., 2009. Iris identification System Using Fractal Dimensions of Haar Patterns International, Journal of Signal Processing, Image Processing and Pattern identification, vol. 2, No.3.
- [32]. Akram, U. M., Tariqy, A., Khan, S. A., 2011. Retinal identification: Personal identification using Blood Vessel, 6th International Conference on Internet Technology and Secured Transactions, United Arab Emirates.

- [33]. Simon, C., Goldstein, I., 1935. A New Scientific Method of identification, New York State Journal of Medicine, vol. 35, No. 18, pp. 901-906.
- [34]. Qamber, S., Waheed, Z., Akram, U., 2012. Personal identification System Based on Vascular Pattern of Human Retina, Cairo International Biomedical Engineering Conference (CIBEC), Egypt.
- [35]. Fatima, J., Syed, M., Akram, U., 2013. A Secure Personal identification System Based on Human Retina, 2013 IEEE Symposium on Industrial Electronics and Applications, Malaysia.
- [36]. Fatima, J., Syed, M., Akram, U., 2013. Feature Point Validation for Improved Retina identification, IEEE Workshop on Biometrics Measurements and Systems for Security and Medical Applications, Italy.
- [37]. http://elektroteknoloji.com/Elektrik_Elektronik/Teknik_Yazilar/Biyometrik_Sistemler_Fiziksel_Ozelliklerden_Yararlanarak_Kimlik_Tespit_Etme_bilgisayar_destekli.html, access: 6.1.2016.
- [38]. Patwari, Manjiri B., Manza, Ramesh R., Rajput, Yogesh M., Saswade, M., Deshpande, M., 2014. Personal Identification Algorithm Based on Retinal Blood Vessels Bifurcation, 2014 International Conference on Intelligent Computing Applications, India.
- [39]. http://www.evrenvebilim.com/kotu_tasarim_yanilgisi.html, access: 11.3.2016.
- [40]. <http://pmgbiology.com/2014/05/31/understanding-the-functioning-of-the-eye-to-a-biology-gcse-part-1/>, access: 11.3.2016.
- [41]. Rashad, M. Z. Shams, M. Y., Nomir, O., El-Awady, R. M., 2011. Iris Recognition Based on LBP and Combined LVQ Classifier, International Journal of Computer Science & Information Technology (IJCSIT), vol 3, No 5, DOI : 10.5121/ijcsit.2011.
- [42]. Bendre, Sandip M., Shivarkar, Raosahe A., An Improved Approach for Iris Authentication System by Using Daugman's Rubber Sheet Model, Segmentation, Normalization and RSA Security Algorithm, International Journal of Computer Technology and Electronics Engineering (IJCTEE) vol. 1, Issue 3 102.
- [43]. Latha, L., Thangasamy, S., 2010. A Robust Person Authentication System based on Score Level Fusion of Left and Right Irises and Retinal Features, Procedia Computer Science 2 (2010) 111–120.
- [44]. Daugman, J., 2007. New Methods in Iris Recognition, IEEE Transactions on Systems, Man, and Cybernetics—part b: Cybernetics, vol. 37, no. 5.
- [45]. Abhyankar, A., Hornak, L. and Schuckersa, S., 2005. Biorthogonal-Wavelets-Based Iris Recognition, Proc.SPIE 5779, Biometric Technology for Human Identification II, 59; doi:10.1117/12.604212.
- [46]. Tian, Q., Qu, H., Zhang, L. and Zong, R., Personal Identity Recognition Approach Based on Iris Pattern, 2011. <http://cdn.intechweb.org/pdfs/16589.pdf>, access: 11.3.2006.

