Chapter 1

Introduction

After September 11, 2001 terrorist attacks, the U.S. Government, other governments and organization’s throughout the world became greatly interested in Human Recognition Technology better known as “Biometric”. Biometric is derived from a Greek word where ‘bio’ means life and ‘metrics’ means to measure. Biometric System refers to an automatic recognition of individuals based on their physiological traits and/or behavioral characteristics. Biometric system became an imperative area of research in recent years. All the authorized government and private sector is interested in most reliable, rapid, safe, convenient and un-intrusive means (system) in order to replace or improve traditional security systems; to recognize a person automatically.

1.1. General Scenarios in Biometrics

Biometric identification is a multidisciplinary approach used in various fields such as medical imaging, satellite imaging, weather forecasting, automated biometrics etc. to improve the security. When a person wants to enter into the high security area or uses credit cards at ATM, their identity should be verified. The traditional method used by people for identification and verification are passwords, identification cards or a physical key. However, physical keys and identification cards can be forged, lost or stolen and passwords can be forgotten. That is why there is tremendous interest in improved methods for reliable and secure identification. The authentication techniques are classified as biometric-based, token-based and knowledge-based techniques as shown in table 1-1.
Biometrics is an authenticated and automated method of recognition of any individual. Suitable biometric is selected and used on the basis of application requirements. There are various biometric systems. For the sake of convenience, they can be classified into two main categories. *Physical biometric* is based on physiological characteristics such as face, finger, iris, retina, hand geometry, palm print, etc. and can be used for both identification and verification. *Behavioral biometric* is based on behavioral patterns like signature, gait, voice, and speech etc. This is shown in figure 1-1. Physiological characteristics are measurable and guaranteed to be unique whereas behavioral characteristics are based on action taken by the person. The data is derived from direct measurement of a part of a human body [20], [21], [56], [103], [110].

There are various upcoming biometrics characteristics such as lip movement, lip shape, nail-bed, nail RFID, cardiac pulse, smile recognition, sclera, tapping recognition etc. Security, convenience and cost are the three basic factors which

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**Table 1-1 Classification of Authentication Techniques**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type of Attribute</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biometric-based</td>
<td>What you have</td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td>Physical Attribute</td>
<td>Iris, DNA, Face, Fingerprint, Palm, Retina</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Behavioral Attribute</td>
<td>Gait, Keystroke, Signature</td>
</tr>
<tr>
<td>Token-based</td>
<td>What you posses</td>
<td>Swipe card, Key</td>
</tr>
<tr>
<td>Knowledge-based</td>
<td>What you know</td>
<td>Password, PIN</td>
</tr>
</tbody>
</table>

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**Figure 1-1 Types of Biometric Characteristics**
influence the adaptation of biometrics. Three immense rationales to use biometrics are to increase security, reduce frauds and cost reduction.

1.2. Overview of Biometrics

Biometrics can not be lost and forgotten. It is very difficult for the intruders or attackers to forge or repudiate any biometric [52]. There are number of biometrics traits available which are used for identification and verification of a person. In verification process, a person claims a particular identity and a biometric system are used to accept or reject the claim. It is done by matching a biometric sample with the previously enrolled sample of the same person. Whereas in identification, the unknown sample is acquired at the time of claim and matched with the previously enrolled known samples. The different possible outcomes of verification and identification are shown in the following figure 1-2.

When a system verifies the identity claim and the claim is true, it is known as true accept and if the claim is false then called true reject. When a system verifies the identity claim and the claim is false, and then false accept occurs whereas if a claim is true then false reject occurs. A true positive occurs when an unknown sample matches a particular person in the gallery and the match is correct whereas the false positive occurs when an unknown person matches a particular person in gallery but the match is not correct\(^1\) [161].

\(^1\)“Biometric Characteristics and Their Applications: A Review”, *International Journal of Computer Science and Application*, (IJCSA 2012), Issue III, pp-06-12, [ISSN: 0974-0767] [161].
A true negative occurs when the sample does not match with any of the entries in the gallery and the sample does not belong to someone in gallery whereas the false negative occurs when the sample does not match with any of the entries in the gallery and the sample does belong to someone in gallery [103], [161].

All the biometric systems work in the same manner. The first process is enrollment in which each new user is registered into a database. A certain characteristic of the person is captured and this information is usually passed through an algorithm. The algorithm converts the information into a template which is stored into a database. The template has a very small amount of information than the original trait. When a person needs to be recognized, then system will take the appropriate measurement, translate this information into a template and match it with the stored template [92]. The authentication and enrollment process is shown in figure 1-3.

Every biometric trait depicts its strength and weakness. On the basis of these criteria’s they are used in different applications. This section describes the various biometrics traits shown in figure 1-4, figure 1-5 and figure 1-6.

1.2.1 Bertillonage

The first biometric ever used is the Bertillonage in 1890. It was created by anthropologist Alphonse Bertillon. Various body measurements are considered such as height, arm length, head length and breadth, finger length, forearm length etc. Vernier caliper was used for measurement. He claims that after the age of 20, the adult bone does not change its length and breadth. Therefore this trait can be used. In
spite of being a simplest and cheap method it was a failure only because unique measurement is available for multiple people [161].

1.2.2 DNA Structure

Medical science has proved that each individual has a unique DNA structure. Forensic science used 13 DNA strands to scan any region. DNA (Deoxyribonucleic Acid) is the one-dimensional ultimate unique code for one's individuality. DNA is highly stable structure and extracted from blood strains, hair, skin etc. Exceptionally, DNA pattern among the identical twins is similar [57], [161]. It has three limitations:

- Intrusive trait as physical sample is needed.
- Expensive laboratory and devices needed for extraction.
- Difficult to extract.

DNA evidences are accountable in many Indian court cases under provisions of Indian Evidence Act, 1872 with view to prove the guilt or innocence [214]. It is also used to identify missing or dead people. DNA is used mostly in paternity test.

1.2.3 Ear

Ear is immutable organ and resistance to the influence of environmental changes. It has various features which are distinct such as shape of ear and cartilaginous tissues of pinna, helix, cymba etc. The image of an ear is captured easily and it has rich and stable structure. Ear piercing is the major problem in its identification [22], [57]. Ear can be covered many times due to hair styles or earrings [3]. Time does not affect the recognition rate. Therefore ear is a time invariant biometric [148].

1.2.4 Iris

Iris is the highly unique organ of human body. It is developed at the sixth month of gestation, fully formed by tenth month and remains stable throughout lifetime of any individual [3] [57]. The irises of right and left eye are not similar. Even iris pattern between identical twins is not similar. It has following limitations:

- Expensive image capturing devices required.
- Difficult to capture an image.
- Cooperation of the subject is must while capturing an iris image.
- Cataract surgery may cause system failure as iris pattern may change [58].
An iris has features such as collarette, crypts, pigment frill etc. The hippus movement and pupil dilation and contraction is used to check (aliveness of any person) whether a person is alive or dead [162].

1.2.5 **Fingerprint**

There are various ridges and furrows available on fingerprints which are used for identification. Fingerprints are unique for each person and each finger. Fingerprint matching is based on minutia based, correlation based or ridge feature based techniques. Dryness of skin, cuts, sweat, dirt, skin diseases, and humidity creates problems in identification [3] [57] [135].

1.2.6 **Face**

Face is the most transparent biometric and the analysis of features is done by finding distance between eyes, nose, jaws edges, mouth etc. Face can be immutable and it has changing structure with age. Therefore database should be updated after every 5-6 years [3] [57] [210]. It is possible to find the age of a person from face biometry [131]. Facial actions are also used to authenticate a person [132].

1.2.7 **Hand Vein**

Hand vein is closer to the surface of the skin than the other veins such as facial veins, retinal veins etc. That is why the vein in hand is always preferred [3] [93] [104]. It can be easily detected through low-resolution camera. It also has limitation similar to finger vein i.e. medical conditions may change the vein pattern and recognition fails. The advantage of this method is having a high accuracy. Hand vein is not affected by harsh environmental changes such as construction site, military bases, manufacturing factories, etc [196].

1.2.8 **Foot Step**

The foot step profiles are gathered from a force plate. For recognition of foot step, the vertical ground reaction force is used for authentication. The ground reaction force is available in three directions such as vertical, horizontal and sideways motion.
An inherent advantage of this system is to capture foot step of the person when other types of biometrics are not available. It enables unobtrusive user authentication [105].

1.2.9 Retina Scan

Retina Scan analyzes the layer of blood vessels situated at the back of an eye internally. The retinal images were used for diagnosis of various diseases by ophthalmologist such as hemorrhages in diabetic patient [3], [92], [148]. It has good verification rate and it consists of rich texture. Retina does not change with age [149], [175], [196].

1.2.10 Lip

Lip biometry is important when partial face part is available. Lip is also able to resist shadow, beard, and rotation problems. Lip prints are also used for authentication. Lip contour are first feature for identification [197]. Colour transform is required for bifurcating lip and skin colour. Variation in lip due to various expressions may create a problem in identification of a claimed identity. The speaker can also be identified with lip recognition [163].

1.2.11 Palmprint

Palmprint analyzes the thick and thin lines and ridges on the palm as features. Palm has more distinctive features. Palmprint is mostly used in law enforcement. Loss of hand in accident, deep burns and cuts may reject the claimed identity [59], [150].

1.2.12 Finger Vein

Finger vein [210] is extracted from the finger image and used as accurate and fraud-proof biometric. The finger vein is highly activated and unique in individuals [198]. Recognition of the vein is quite difficult as vein patterns may change due to medical conditions.

1.2.13 Gait

Gait is the way in which a person walks. It reflects the behavioral biometrics. It is used to identify a person from longer distance. The features are movements of different body parts. Change in floor, footwear and cloths may reject the claimed identity.
identity. The change in human age changes the gait patterns. That is why age factor denies the claimed identity. The video sequence footage is used for gait feature extraction [57], [68], [78], [119], [133]. Gait recognition is most useful for surveillance. This is only because it can be captured without the consent of the person being observed. Other factors which might affect gait are stimulants like alcohol and drugs which makes a person unbalanced, physical changes due to pregnancy, accident, after weight gain or weight loss and person’s mood [196].

1.2.14 Keystrokes

Keystroke dynamics, a behavioral biometric based on the dynamic features such as time duration between keystrokes, inter-keys delay, dwell time that is how long a person holds down a key etc. The hardness of keyboard of computer, laptop or typewriter may create a problem to get the correct features [34], [120], [161]. Major disadvantage of this trait is that the person has to type without mistakes [196]. Minimum 20 to 100 strokes are basically snooped for forgery within a short time span [176].

1.2.15 Signature

Signature is the behavioral biometric used to identify a person in banks, postal services, colleges etc. Tablet is used to capture 2-Dimentional signature. It works on stroke order, pressure while signing, direction and the speed. It can be forged easily [3], [57], [120], [131], [134]. The digitized signature looks different than the usual signature. While signing, user is not able to see anything on the tablet. User needs to look into the monitor to see what he/she has written [106].

(a) Palm-print (b) Finger Vein (c) Gait (d) Keystroke (e) Signature

Figure 1-6 Examples of Biometrics

1.3 Comparative Study of Biometric Technologies

For any biometric system to work properly, there are various biometric identifiers which are very important. These biometric identifiers [57] allow understanding about which biometric technique is the best technique to follow.

- **Universality** Every person has the characteristic.
• **Uniqueness** Varies across users (No two persons have it alike).
• **Permanence** The characteristic should not invariant (change) with time.
• **Collectability** The characteristic can be easily obtained and measured quantitatively.
• **Performance** Low error rate and better accuracy.
• **Acceptability** Up to what extent people are willing to accept the biometric system.
• **Circumvention** How easy to spoofed or fools the system.

By considering all the above biometric identifiers, the comparative chart as shown in table 1-2, is prepared to find the best biometric technique. From the table it has been observed that not a single system supports all the identifiers. Each biometric trait has its own advantages and disadvantages [57].

<table>
<thead>
<tr>
<th>Biometrics</th>
<th>Universality</th>
<th>Uniqueness</th>
<th>Permanence</th>
<th>Collectability</th>
<th>Performance</th>
<th>Acceptability</th>
<th>Circumvention</th>
</tr>
</thead>
<tbody>
<tr>
<td>DNA</td>
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<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Ear</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Face</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Face Thermogram</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Fingerprint</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Gait</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Hand Geometry</td>
<td>Medium</td>
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<td>Medium</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Hand Vein</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Iris</td>
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<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Keystrokes</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Odor</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Retinal Scan</td>
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<td>Medium</td>
<td>Low</td>
<td>High</td>
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<td>High</td>
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<tr>
<td>Signature</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Voice Print</td>
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<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

Biometric recognition has been a very challenging and difficult problem. In spite of the great work done in the last many years, the research community will have to work, at least, the next 30 years to completely solve the problem. Strong and coordinated effort between the computer visions, signal processing, iridology and neurosciences communities are needed. The *International Biometric Group* (IBG)
shares a global market by technology. This is shown in figure 1-7. Iris recognition is expected to comprise approximately 16% of the entire biometric market by 2015 [211].

![Figure 1-7 Comparative Market of Biometric Technology [213]](image)

The accuracy of any biometric implementation is sensitive to the target population. For successfully applying a biometric technology to a personal identification system, it is important to understand and realistically evaluate the technology with respect to target application and target population. The cost of any biometric system is tied to its accuracy. The cost of iris recognition is much more but it provides the greatest accuracy [57]. This is shown in figure 1-8.

![Figure 1-8 Cost Vs Accuracy of Biometrics [57]](image)

### 1.4 The Human Iris

The human eye is a complex anatomical device and remarkably demonstrates the architectural wonders of the human body. The eye is working like a camera. The eye is able to refract light and produce a focused image which can stimulate neural responses and enable the ability to see [53]. The eye is approximately a spherical shell which is transparent at the front portion and opaque (or nearly so) over the remaining
eighty per cent of its surface. The optical path consists of a series of transparent liquids and solids. The human eye structure and physiology is shown in figure 1-9.

Human iris is visible through the clean cornea as disc inside the eye. The iris is a diaphragm of variable size. Its function is to adjust the size of the pupil so that it can regulate the amount of light admitted into the eye. In general, the iris is a coloured part of the eye in nature. It may be of many shades of blue, green, brown, hazel, or grey etc [11]. It is a coloured membrane of the human eye hanging in front of the lens. It is attached to ciliary body and open to pupil i.e. centrally it ends at the papillary margin. From the front side (anteriorly) it is lined by a layer of endothelium. From the inner side it is having iris stroma (which has spongy connective tissues, pigment containing chromatophore, vessels, and nerves) and two muscles [33]. These two muscles are referred as two basic regions as given below:

1. Central papillary zone (contains spincher muscles)
2. Periphery ciliary zone (contains dilator muscle).

Posteriorly, two layers of epithelium line the iris. The junction is a circular ridge called “collarette” is generated through the muscle movement form both regions [199]. The iris stroma is a loose fibrocollagenous tissue composed of spindle shaped fibroblasts (stromal cells), blood vessels, nerves and macrophages containing phagocytosed melanin pigment.

The iris contains pigmented cells and muscle as shown in figure 1-10. Iris is composed of four layers:

- The anterior border layer (endothelium).
- The stroma : consisting of fibers and cells.
- The dilator muscle and spincher muscle layer.
- Posterior Epithelium.
The anterior border layer consists of a dense packing of pigmented or non-pigmented cells. These pigmented and non-pigmented cells are similar in appearance to the cells present throughout the remaining part of the stroma as shown in figure 1-11. Absence of cells produces the crypts in the border layer. A circular bundle of smooth muscles running around the pupillary margin which causes contraction of pupil are called Spincher muscle.

When bright light reaches the retina, nerves of the parasympathetic nervous system are stimulated. Then a ring of muscle (Spincher) around the margin of the iris contracts, so the size of the pupil is reduced. Therefore less light is able to enter the eye. Whereas when dim light reaches the retina, the pupil opens due to stimulation of the sympathetic nervous system. This contraction of radiating (Dilator) muscles is allowing more light to pass inside the eye. Therefore the size of the pupil is increased.

The transverse section of human iris shown in figure 1-12; shows anterior layer, stroma, posterior layer, pigment frill and lens. The anterior layer is visible to us called endothelium. This bears the gaily-coloured relief and it is very lightly pigmented due to genetically determined density of melanin pigment granules. It consists of a dense packing of pigmented or non-pigmented cells. These pigmented and non-pigmented cells are similar in appearance to the cells present throughout the remaining part of the
stroma. Absence of cells produces the crypts in the border layer. A circular bundle of smooth muscles running around the pupillary margin which causes contraction of pupil are called Spincher muscle. The posterior layer is invisible to us and it is highly pigmented.

Figure 1-12 Section through the Human Iris [11]

In between these two layers the stroma is present. The iris stroma is a loose fibro-collagenous tissue composed of spindle shaped fibroblasts (stromal cells), blood vessels, nerves and macrophages containing phagocytosed melanin pigment. The pigment frill is the boundary between the pupil and the iris. It looks like a curling edge of the pupil shown in figure 1-13. The anterior layer consists of ciliary and pupillary area. The boundary between both these areas is called collarette. The junction is a circular ridge called “collarette” is generated through the muscle movement form both regions [33] [45] [46] [200].

Figure 1-13 Transverse Section of Human Iris [11]

The anterior surface of the iris has various visible features of the human iris which are important to identify a person. These are specially pigment related features and the features controlling the size of the pupil, visible rare anomalies, pupil, pigment frill and collarette. Crypt and the pigment spot are the pigment related features shown in figure 1-14 (a) and (b). The crypt is the area in which the iris is relatively thin. They have very dark colour because of the dark colour of the posterior layer. They appear near the collarette, or on the periphery of the iris. They look like sharply demarcated excavations. The pigment spots are random concentrations of
pigment cells in the visible surface of the iris. They are generally appears in the ciliary area. They are known as moles and freckles. They have nearly black colour.

The features which control the size of the pupil are radial and concentric furrows. The contraction furrows controls size of pupil whereas radial furrows begin near the pupil and extend through the collarette. The radial furrows are creased in the anterior layer of the iris, from which loose tissue may bulge outward. And this is how it permits the iris to change the size of the pupil. The concentric furrows are generally circular and concentric with the pupil. They typically appear in the ciliary area, near the periphery of the iris. They permit to bulge the loose tissue outward in different direction than the radial furrows.

Collarette is the boundary between the ciliary area and the pupillary area. The collarette is the thickest part of the iris.

1.5 Why Iris Recognition?

Iris recognition is one of the most appropriate biometric systems and considered to have the best result like DNA pattern. Iris biometric has various advantages over other techniques.

Degree of Freedom – It has been mathematically proved that iris has sufficient degree of freedom; approximately 400 distinguishing characteristics out of which 260 unique features are measured for identification. Among all the biometrics iris has the highest degree of freedom [103].

Protected- Iris is protected from external environment behind the cornea and the eyelid as compared to fingerprint, face, palm-print, ear etc.

Non-intrusive- The biometric traits such as signature, fingerprint, face etc are appropriate for bank transactions and providing entry into secure areas, these
technologies have the disadvantage that they are intrusive both physically and socially. Iris is non-intrusive in nature. Iris imitation is hardly impossible.

**Intra-personal variation** - This variation in physical characteristic is smaller than behavioral characteristics. Other biometric traits such as face, gait, keystroke, voice etc are the changeable patterns and they shows variation with changing age. The dryness of skin, skin disease, sweat, dirt or humidity degrades the quality in fingerprint and palm-print recognition [103]. For example, a signature is influenced by both controllable actions and less psychological factors. A speech patterns is influenced by current emotional state, whereas fingerprint template is independent. That is why all the physiology-based biometrics does not offer satisfactory recognition rates [60], [81]. However iris is not showing any intra-personal variation.

**Accuracy** - Iris recognition offers the highest accuracy in identification of any individual. Every iris is unique. It is developed at the sixth month of gestation and fully formed at the 10th month. It remains stable throughout the life and does not change with age. Two irises of identical twins and irises of left and right eye of the same person are not similar [212].

With the current scenarios, when compared with other biometrics, iris recognition is not used in more number of applications. This is only because the camera or sensor is very expensive rather than any other biometric systems such as fingerprint or face. However, no other biometric technology can match iris recognition for its accuracy of identification and authenticity in the system.

### 1.6 Iris Recognition

Iris recognition systems are developed as computer program which analyzes human iris images to identify a person. A typical iris recognition algorithm includes five stages commonly: image acquisition, Localization, Normalization, Feature Extraction and Matching. In some iris recognition systems the contrast of iris image can be enhanced using iris enhancement. This is done before the feature extraction phase. This process is accomplished in five steps:

1. **Iris Acquisition** : Used to acquire the iris image from the available database
2. **Iris Segmentation** : To localize the iris annular region from the whole image.
3. **Iris normalization** : To compensate for the deformation of iris texture.
4. **Feature Extraction and encoding** : Analyze the spatial geometry of distinguishing features of the iris and encode the iris pattern.
5. **Iris Matching**: Sample is matched with the stored template.
   - **Verification**: The general template is only compared with one template in the database that of the claimed identity.
   - **Identification**: This process yields scored that indicates how closely the generated template matches each of those in the database.

6. **Result**: On the basis of score obtained from fourth step, declares a match of accept or reject [95].

### 1.7 Advantages and Disadvantages

‘Iridology’ is a science used in Rumania and California. In this, the differences of crypts and pigmented spots are considered to determine the specific organ to fall ill. But today it is treated as Medical fraud. Using human iris for identification, there are many advantages and disadvantages.

1. **Advantages**
   - Iris is stable throughout the life.
   - It is visible from a distance.
   - It is highly protected internal organ of an eye.
   - Limited genetic penetrance.
   - Iris pattern posses the high degree of randomness.

2. **Disadvantages**
   - It is a small target of approximately 1cm.
   - It can be acquired from 1 meter distance.
   - It has continuous movement.
   - Located behind curved, wet and reflecting lens
   - It is obstructed by eyelashes, eyelids and reflections.
   - As pupil changes size, its deformation is non-elastic.

### 1.8 Applications of Iris Recognition

There are various applications in the real world where iris can be used. These are shown in figure 1-15.

1. **Identity cards and passports**

Iris can be used on identity card and passports to recognize students, visitors and foreigners to avoid problematic situations occur due to change in get-up, contact lenses etc. For example in Pakistan, Bio-ID Technologies for UNHCR repatriation
project used iris to control aid distribution for Afghan refugees. At Schiphol Airport, Netherlands, iris recognition has permitted passport free immigration since 2001 [212].

2. **Border control**

Iris database for all the soldiers and dignitaries should be maintained, so that any unknown and unauthorized personality should not cross the border and join our security forces.

![Figure 1-15 Applications of Iris Recognition](image)

3. **Government programs**

Iris recognition can be used in various government programs like immunization, vaccination, election security, identifying criminals etc. For example, a U.S. Marine Corps Sergeant uses an iris scanner to identify a member of the Baghdadis city council prior to a meeting with local tribal figureheads, sheiks, community leaders and U.S. service members [120].

4. **Database access and computer login**

Big research industries can use iris recognition for access inside the building, database, and even for computer logins. Educational institutes can manage Admission data, Exam data, and Marks entry with database access and server login with identified person.

5. **Hospital and Aviation security**

Entry into the operation theatre, ICU, Stock Room, blood bank, criminal patient's room can be restricted with iris recognition. Entry into an Aeroplane, Aerodrome while immigration checks and Cargo should be restricted.
6. **Controlling access**

To achieve security, access control can be provided in Banks, clubs, libraries and ATM’s [177].

**1.9 History**

The idea of using the iris as a distinguishing human identifier was suggested in 1885 by French physician Alphonse Bertillon. He had described both colour and pattern type. In 1949, British ophthalmologist James Doggart commented specifically on the complexity of the iris patterns and suggested that the iris patterns can be used for matching as fingerprints [32].

The uniqueness of the iris patterns was discovered by the ophthalmologist Leonard Flom and Aran Safir in 1987, but they had no algorithm. After this discovery, John G. Daughman, a professor of Cambridge University, suggested an image processing algorithm that can encode the iris pattern into 256 bytes based on the Gabor transform [200].

Iris recognition begins with finding an iris pattern in an iris image, demarcating its inner and outer boundaries at pupil and sclera, detecting the upper and lower eyelid boundaries if they occlude, and detecting and excluding any superimposed eyelashes, or reflections from the cornea or eyeglasses. These processes may collectively called Segmentation [22].

The complex iris texture is very distinctive and carries information which is useful for personal recognition [54]. The accuracy and speed of currently deployed iris-based recognition system is promising and support the feasibility of large scale identification systems based on iris information. It is also possible to detect contact lenses printed with a fake iris.

The hippus movement of the eye may also be used as a measure of live-ness for this biometrics. Early iris recognition systems required considerable user participation and were expensive, where as newer systems have become more user-friendly and cost-effective [32]. Commercially speaking no one has any public deployment using their own proprietary algorithms even though there are various algorithms available. Iris recognition is used in Hajj Pilgrims in Saudi Arabia.
1.10 Objective and Motivation

Iris recognition has been a very challenging and difficult problem. In spite of the great work done in the last many years, it is sure that the iris recognition research community will have to work, at least, the next 30 years to completely solve the problem. Strong and coordinated effort between the computer visions, signal processing and iridology and neurosciences communities are needed. The percentage of Iris recognition in Biometric Market is just 16% in 2015 [211].

To extract various features like inner and outer boundary of iris, ridge, contraction furrows, pits, rings, collagenous fibers, filaments, crypts (darken area of the iris), and freckles, lower and upper boundary of eyelid for iris recognition using advanced image processing technique through multi wavelet approach. Wavelet based coding provides substantial improvement in the picture quality at higher compression ratio. Due to implementation constraints, scalar wavelets do not possess all the properties which are required for better performance. The multi wavelet possesses more than one scalar filter.

The multi wavelet has several advantages upon scalar wavelet. The features such as compact support, orthogonality, symmetry and high order approximation are needed for image processing. The multi wavelet system can simultaneously provide perfect reconstruction while preserving length (orthogonality), good performance at the boundaries, and high order of approximation [73]. That is why the proposed work is to extract features and apply normalization technique with multi-wavelet transform. This work may help to increase the robustness of iris recognition system.

The objective of this work is:

- To extract iris image features by using different frequency domain techniques such as wavelets and multi-wavelets.
- Identify the problems associated with existing iris recognition systems and possible avenues of research that may help to address these issues.
- To study various segmentation and transform techniques for feature extraction of Iris image.
- To study the effect of different wavelet and multi-wavelet based techniques on iris image feature extraction.
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- To determine the most effective method of combining methodologies of multi-wavelets from the range of iris recognition techniques, in order to achieve a more effective iris recognition system.
- To evaluate the quality measures for iris feature extraction using different wavelet, and multi-wavelet transformations.

1.11 Organization of Thesis

This chapter is an introduction to the work, gives an overview of the research work, and states the motivation, aims and objectives with respect to iris recognition. Chapter 2 firstly discusses the literature survey on Segmentation, secondly on normalization. Thirdly focuses on Feature Extraction with multi-wavelet based feature extraction techniques. Chapter 3 comprises our proposed methodologies for iris feature extraction. Experimental work, experimental results, discussion and interpretation about our findings are discussed in chapter 4. Chapter 5 comprises the conclusion and future work of the system.