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# IRIS PATTERN RECOGNITION: A QUANTITATIVE REVIEW ON HOW TO IMPROVE IRIS-BASED PATTERN RECOGNITION SECURITY SYSTEM

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**ABSTRACT**

The biometrics is a reliable authentication process for identifying individuals. Iris pattern recognition is a booming sector in biometric which has high accuracy in identification/authentication. The iris-based security system required an infra-red camera or video camera for the authentication process. This paper reviews several well-known Iris pattern recognition techniques that are used for authentication by biometric identities of iris. This work also discusses facts and downsides in the existing iris pattern recognition techniques.

**Disciplinary**: Ophthalmology, Computer Science and Informatics Engineering.



## 1. INTRODUCTION

Biometrics is one of the booming sectors in the authentication of a person which is becoming most widespread. The word ‘Biometric’ is defined from the Greek word ‘Bio’ meant for life and ‘Metric’ meant for measure [1]. For authentication or identification of a person by automatic recognition technology depends upon the physiological and behavioural characteristics of a person. Biometrics are even deployed in nationwide identity cards and even in payment methods using mobile [25]. The most prominent body characteristics of a human are used to recognize each other by face, voice, and gait for hundreds of years. In Paris, identification of criminal’s department head in the law enforcement, Alphonse Bertillon has embellished and accomplished the methodology of employing the numbers of human body measurement for identifying the criminals and discovered the distinctiveness in the human characteristics [2]. In the body characteristics, the law enforcement collects the fingerprints of the offenders are stores in their respective database as an image file, and

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matches are made with obtained fingerprints with the collected database to find the identity of the criminal. The behavioural and physiological attributes are a biometric identity of a human when it satisfies Universality, Collectability, Distinctiveness, and Permanence [2]. Universality means every person should have the Attribute. Distinctiveness means every person should have different attributes of both physiological/ behavioural. Permanence means over a period the physiological/behavioural characteristic should be invariant for the matching criterion. Collectability means the character can be measured quantitatively.

## 1.1 HUMAN EYE

The eye is an inner organ of a human body that reacts to the light which has various purposes with distinct features [3] and allows vision. In the eye, the retina permit conscious light perception which has Rods and Cones cells, and the perception of depth and the Colour differentiation are included in the vision. Approximately ten million colors can be distinguished by the Human eye [10] [32]. The retina in the eye has non-image-forming photosensitive ganglion cells which observe the light signal will adjust the size of the pupil by regulating the suppression and compression through hormone melatonin of the body clock [33].

### 1.1.1 STRUCTURE OF HUMAN EYE

The shape of the eye is not a well-formed sphere shape but a fused two-piece hemisphere unit. The curved and transparent part in the smaller frontal unit is known as the cornea which is linked to the larger white unit which is known as the sclera. The corneal segment is about 0.3 inch which is almost 16 mm in diameter. The five-sixths construct the other sclerotic chamber which is having a diameter of 25mm. The sclera, cornea which is well structured with a ring is said to be limbus. The iris is present in the centre of the eye which is of colored circular structure which is concentrically surrounded by the pupil, it appears to be black. The percentage of light which passes to the eye is controlled with a pupil which regulates the light by adjusting the pupil dilator and sphincter muscles. The device which is used to view the inside of the eye is known as the ophthalmoscope. Figure 1 shows the anatomy of the human eye [3].

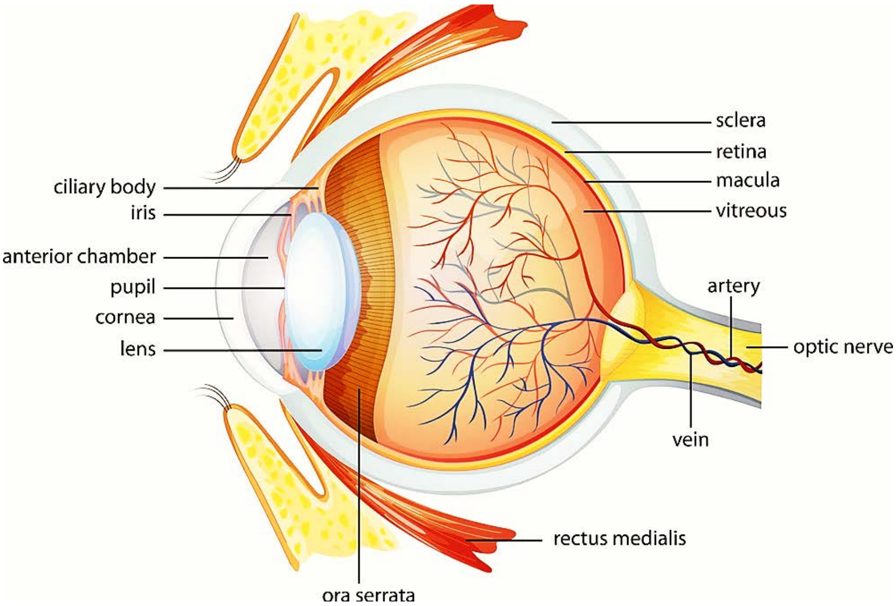


**Figure 1**: Anatomy of the human eye.

(Source: http://www.exetereye.co.uk/the-eye/eye-anatomy ©2020 Exeter Eye).

The light-sensitive cells in the retina will convert the light falling on it to the electrical signals in which have been passed to the brain via nerves [3].

### 1.1.2 SIZE OF HUMAN EYE

The dimensions of the human eye differ by one or two millimeters for the adults and the remaining with consistent across various ethnicities. The vertical measures will be usually lesser when compared to the horizontal measure of 24 mm in range. The crosswise size of an adult eye is approximately 24.5 mm and the size of sagittal is approximately 23.8 mm with no difference with the gender and the age groups. In the centre of the transverse radius and the orbit width of 0.89 (r) which has a strong correlation has been found [34]. Typically, the eye of the adult has the anterior to posterior with a radius of 12.5 millimetres, and a cubic volume of 6.2 cubic cm which is of 0.41 cu.inches [35] and with a weight of 7.7 grams. The growth of the eye which rapidly increases in a range of 15.2-18.5 millimetres of about 0.68 inches at the birth with 23.6-24.1 mm which is approximately 0.9 inch in 3 years of age. At the age of 13, the human eye will obtain its full size.

### 1.1.3 DYNAMIC RANGE OF HUMAN EYE

In the human eye, the ratio of the retina is of 100000:1. The pupil in the eye is automatically re-altering the pupil size depends on exposure when the eye movement is made by the human (saccades) [36] [37] by both physically and chemically. With the uninterrupted darkness, the normal human eye takes approximately 4 seconds for adapting to the darkness. Where the full adaptation of darkness happens only after thirty minutes in the retinal chemically is known as the Purkinje Effect. Therefore, when the light is interrupted in the darkness adaptation the process of adaptation must starts from the beginning again. The darkness adaptation will take place depending upon the good blood flow in the eye. Due to poor blood flow or circulation in the human the darkness adaptation may be hampered. The lens in the eye is just like the lenses which are found in the optical instruments such as the camera and the principal for the lens in the eye as in the cameras. The aperture which performs the operations in the camera is the same functionality that the pupil does in the human eye. The iris act as a diaphragm which acts as an aperture stop. The typical size of the pupil is 2mm in radius which normally ranges from 1.2mm/f/8.4 in a bright place to 4.3mm/f/2.2 in the dark. With age the letter value will vary, for the old people the eye will dilate with the range of 5-6 mm [38] [39].

## 1.2 PUPIL CONSTRICTION

In the edges of the lenses, the light cannot be refracted. Any type of lens which produces the image across the edges of the circular aberration would be faint.

## 1.3 IRIS ANATOMY

Iris in the Human eye is a circular thin layer for adjusting the size of the pupil by controlling the iris diameter to allow the percentage of light which passes through the pupil which reaches the retina. The eye colour is differentiated as per the iris [4]. And the remaining will be known as the ciliary zone. The thickest region in the iris is the collarette which separates the pupillary potion from the ciliary portion [41]. The most peripheral and thinnest part of the iris is the root [42].

## 1.4 EYE COLOUR

Usually, the iris is a strong pigment in the eye where the colour of the iris ranges between blue, brown, hazel, and grey. Occasionally, due to the absence of pigmentation in the eye, the colour of the iris will change due to the oculo-cutaneous albinism [41] into the pinkish-white. When combining the effect of pigmentation, blood vessels, texture, and fibrous tissue which are occurred in the iris stroma where the iris colour is the highly complex phenomenon which makes the individual's epigenetic constitution [42]. In the iris, there is a two very distinct colour which having the melanin in the hazel eyes which had the blotches of mixed hues [43].

## 1.5 IRIS RECOGNITION

Iris recognition is the process of automatic identification of a person using mathematical pattern recognition techniques using the data obtained from the images of one iris or both irises from a person whom patterns are unique in nature [5]. The performance of the iris recognition system in the context of video-based distant acquisition [24] can be improved from the effects of degradation using pixel-level quality criteria fusion techniques. Few factors determine the quality of iris biometric data [27] which includes focus, the angle, level of occlusions, the area of focus, pupillary dilations, and also the level of pigmentation in the iris.

## 1.6 ADVANTAGE

In the eye, the iris is said to be the best part of the human body which will be versatile from the biometric identification. Iris can be taken as the photograph in a range of distance of 10 cm to less than a meter away [46]. The most commonly established iris algorithm was Daugman's Iris code which has the unpredictable false rate which is better than the Hamming threshold distance of 0.26 with imaging noises, reflection, and so on still declared the to be matched [47].

## 1.7 DEPLOYED APPLICATIONS

The biometrics finds its way in many applications such as International Border control. The iris pattern as a live passport identity [48], Password for systems, Ticket-less travel, Cell phones and other authentication using wireless-device, Safer access to accounts in the bank, Rights to services authentication, Access control for premises that is House, Office, and Lab, Vehicle Driving Licence and control of access to privileged information.

## 1.8 MULTI-MODEL BIOMETRIC SYSTEM

The biometric security model is the only one that will provide a correct, secure, and reliable scheme for personal verification. Biometric security is broadly categorized into Uni-modal and Multi-modal. When the information is acquired from a single biometric attribute may be corrupted by unwanted data but the multi-biometric systems are insensitive to the unwanted data on the sensed data. These systems also help in extending the tracking or monitoring of the person in a situation where the single biometric attribute is not enough [49]. There are four different modules in biometric systems as given in Figure 2 which are: Sensor Module: attribute is captured in the form of raw biometric datasets. In the feature extraction module: It processes the captured data to extract an important feature set. Matching module: It compares the extracted feature set with the template stored in the database to generate matching scores with the help of some classifiers. Decision module: It uses the results obtained from the matching score module to either determine an identity is genuine or fake or validate a declared identity [43].

## 2. RESULTS OF REVIEWS AND FINDINGS

### 2.1 ROTATION INDEPENDENT AND LIGHTING VARIATIONS OF IRIS RECOGNITION

Under various lighting conditions, the accuracy of the detection of the iris is done by brightness normalization that helps to extract the iris region. Various investigations for the orientation of iris and shape recognition have been done for sophisticated and unsophisticated irises. The FRS (False Acceptance Rate) was 0% when the decision threshold criteria were at or below 0.25 even through the false rejection rate was about 13%. By this method using the lesser distance as the shape recognition criteria, the output shows where the unregistered iris is rejected exactly. The combination of lesser distance with R-SAN can recognize both the unlearned irises and the learned irises patterns by arbitrary orientation [7].

#### 2.1.1 PERFORMANCE OF ORIENTATION RECOGNITION

The attributes of orientation recognition of unsophisticated and sophisticated irises are examined by using the datasets that are captured in the indoor lighting variation having emittance of 300lx. In Figure 3 the performance is shown below with the horizontal axis as the input rotational angle of the iris, and the vertical axis represents the recognition orientation. Figures 3(a), 1(b), and 1(c) have the exact values of large emplacement recognition error with 1.39°, 2.31°, and 4.38°, respectively. Thus, the result suggests that the emplacement recognition of unsophisticated irises is deliberately scattered, Figures 2(a), 2(b), and 2(c) [7]. Figure 3, the attributes of the orientation recognition execution for Sophisticated irises in Three sessions, (a), (b), and (c). with 4 subjects, 6 subjects, and 12 subjects, respectively.

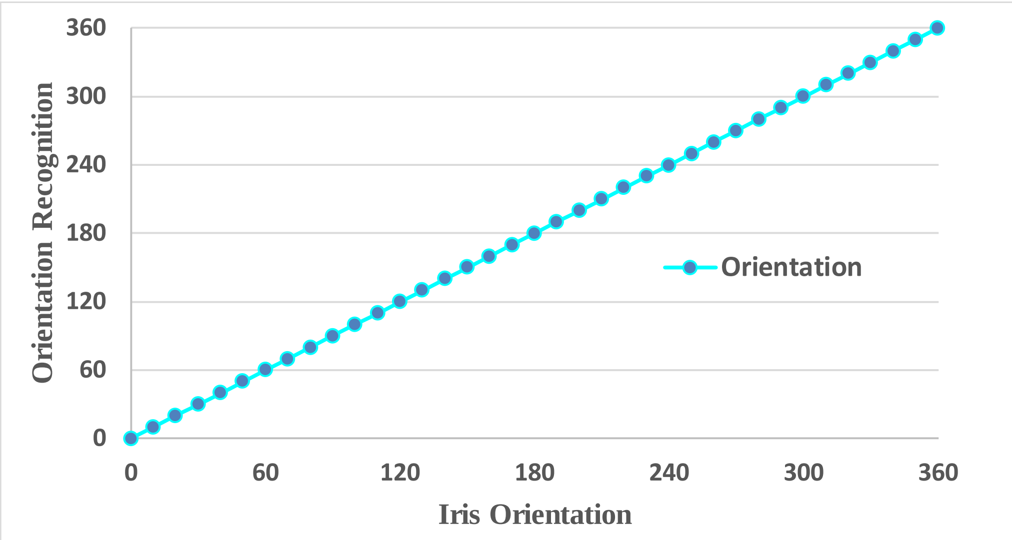


**Figure 2(a)**: Orientation Recognition for four subjects.

#### 2.1.2 PERFORMANCE OF SHAPE RECOGNITION

In Figure 4, the performance of shape recognition for an unlearned iris in which the horizontal axis shows the decision theory of shape neuron result and the vertical axis shows the FRS. In which this result shows that for an unlearned iris the false acceptance rate was 39% even though the decision threshold of the shape recognition neuron result was 1 [7].

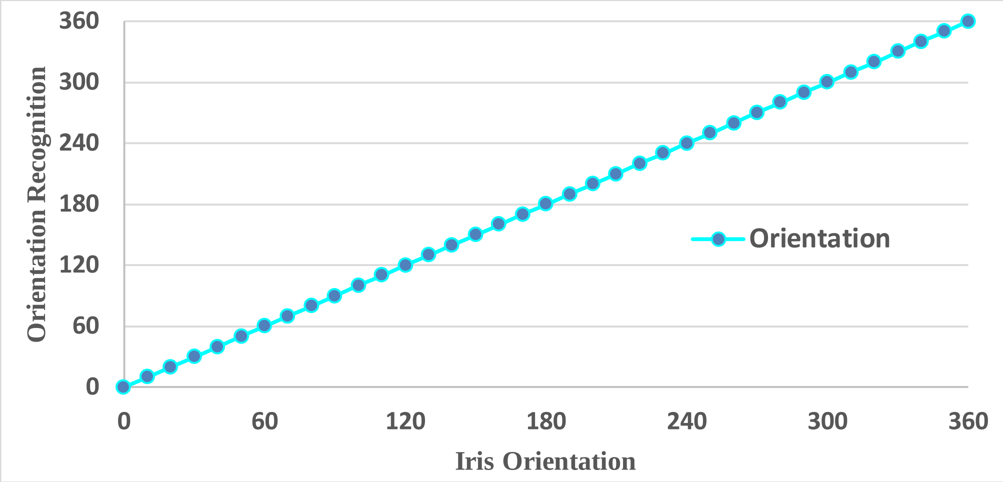


**Figure 2(b)**: Orientation Recognition for six subjects.

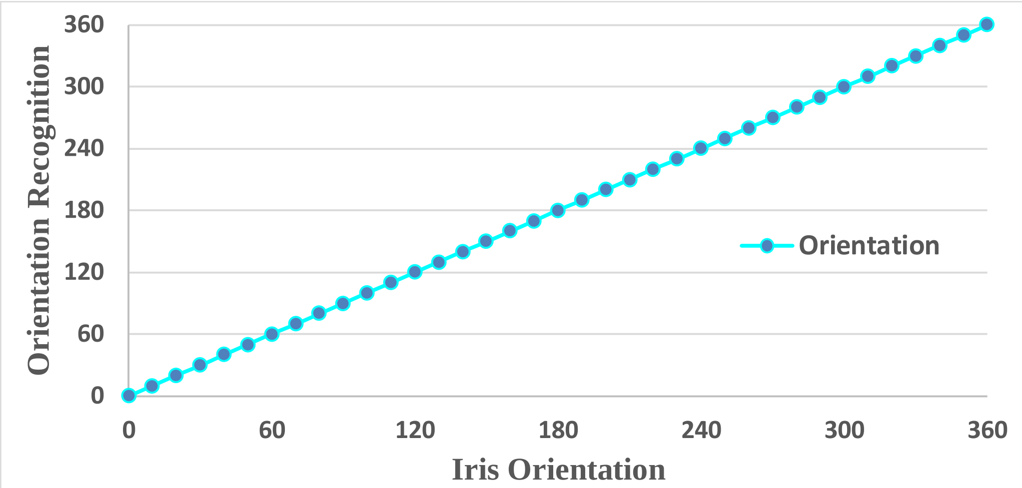


**Figure 2(c)**: Orientation Recognition for 12 subjects.

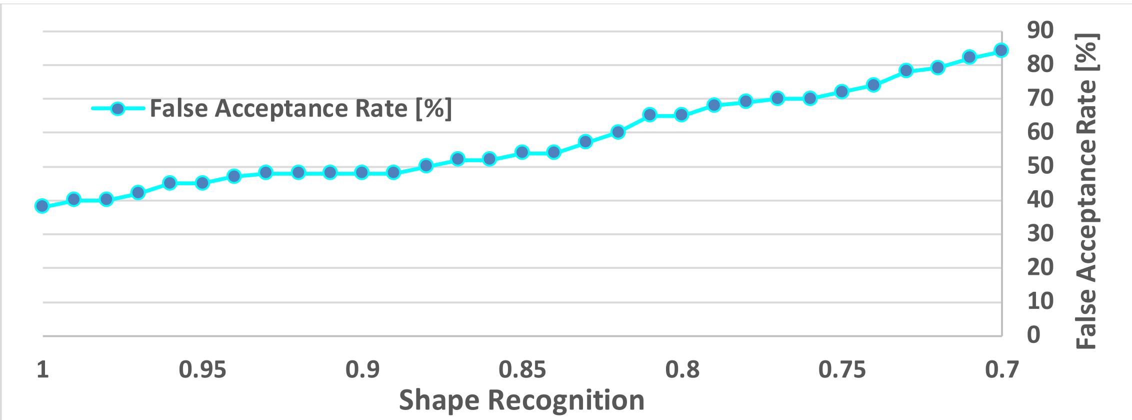


**Figure 3**: False Acceptance rate of Un-learned Iris.

### 2.1.3 EXPERIMENT ON IRIS LOCALIZATION THROUGH VARIOUS LIGHTING CONDITIONS

The output under various lighting conditions which are in Bright Condition without brightness normalization as 69.7% and with brightness normalization as 91.3%. Similarly, in Dark Condition with brightness normalization as 88.3% and without brightness normalization as 0%. In this technic, FRS is 0 % and the False Rejection Rate (FRR) is 13%.

## 2.2 PERFORMANCE OF LONG TERM AND SHORT-TERM IRIS RECOGNITION EVALUATION

So far the influence on aging in segmentation vs feature extraction has not been considered. To shed light on the impact of quality in segmentation when assessing aging effort on the observed temporal effect on lighting, the results have been recorded for the long-time span of about 4-years' time-lapse of the database with 36,240 images which comprise of 104-classes with a variety of recording constrain of datasets highlighting the crucial role of a transparent capturing setup [8]. The threshold value in the biometric security system for its FRS, FAR, and when these values are equal, with these common values have been referred to as the equal error rate.

## 2.3 AGING EFFECT

For a human, the age between 20 and 60 the existed pupil size in the eye will reduce by 14% only. The repeated exposure of the eye to the low-level light and loud sound which inductees the Fatigue will reduce the existing pupil size to 60% for the old age group and 70% for the young age group which resulted as the fatigued existing pupil of both categories will be about 4mm. With age, the relaxed size of the existing pupil will change. The dark-adapted pupil and the size of the relaxed eye are 7mm in the frequency which is quoted by the astronomer. The relationship between the dark-adapted pupil and the age has been expressed by the following equation given below [57][9].

$$\text{Pupil Size} = 6.9\text{mm } e^{(0.5 * [Age/100]^{\wedge}2\ )} \quad (1)$$

Table 1 shows the equation of Schaefer's pupil with respect to age and adapted pupil size [9].

**Table 1**: Schaefer's age with eye-pupil size equation - dark-adapted pupil size and age.

| Age (Years) | Pupil in mm |
|---|---|
| 10 | 7.1 |
| 15 | 7.0 |
| 20 | 7.0 |
| 25 | 6.9 |
| 30 | 6.8 |
| 35 | 6.7 |
| 40 | 6.6 |
| 45 | 6.4 |
| 50 | 6.3 |

**Table 2**: Pupil-Eye Statistics (Kadlecova's)

| Age (years) | Pupil size (mm) | | |
|---|---|---|---|
| | Pupil Size (Average) | Upper SD | Lower SD |
| 8 | 7.5 | 8.1 | 7.1 |
| 20 | 7.1 | 7.8 | 6.9 |
| 30 | 7.1 | 7.7 | 6.6 |
| 40 | 6.8 | 7.4 | 6.1 |
| 50 | 6.3 | 7.1 | 5.4 |
| 60 | 5.9 | 6.9 | 4.8 |
| 70 | 5.9 | 6.3 | 4.7 |
| 80 | 5.3 | 6.3 | 4.1 |

The variation in pupil size for Normal dark-adapted pupil has been given in Table 2. In which the size of the pupil is reduced for the age group between 8-60, which is 1mm diameter approximately.

**Table 3**: Pupil-Eye statistics (Kumnick's)

| Group No | I | II | III | IV |
|---|---|---|---|---|
| Age | 7.4-15 | 18.2-28.3 | 30.4-52.6 | 70.3-90.7 |
| Number in group | 21 | 25 | 24 | 24 |

Table 3 shows the age group 8-91 years was estimated by the naked eye for limiting the magnitude in a starfield. The Groups/Clusters have been formed by age intervals of 7.5-15 in Group I, 18.1-28.2, in Group II 30.5-52.7 in Group III, and 70.4-90.8 in Group IV with numbers of 21, 25, 24, 24 persons in groups. Table 4. Shows the average pupil size in Initial/Normal light condition for the group. Table 5. Shows the average pupil size after 10 minutes of Dark Adaptation for the group.

**Table 4:** Initial size in light

| Group | I | II | III | IV |
|---|---|---|---|---|
| Average Size under Light Constructed | 4.2 | 4.2 | 3.7 | 3.2 |

**Table 5**: Initial size at dark adaptation (After Ten Minutes)

| Group | I | II | III | IV |
|---|---|---|---|---|
| Average Size in Dark | 7.0 | 6.9 | 5.8 | 4.8 |

**Table 6**: Pupil Fatigue after repeated exposure in the faint light

| Group | I | II | III | IV |
|---|---|---|---|---|
| Average Size light constructed in fatigue | 4 | 3.9 | 3.6 | 2.9 |

**Table 7**: Minimum Magnification of the Pupil size

| Age | Pupil mm | Magnification Applied | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 7.1 | 5 | 12 | 14 | 16 | 18 | 23 | 30 | 37 | 45 |
| 15 | 7.0 | 5 | 12 | 14 | 16 | 18 | 23 | 30 | 38 | 45 |
| 20 | 7.0 | 5 | 12 | 14 | 16 | 19 | 23 | 31 | 38 | 45 |
| 25 | 6.9 | 5 | 12 | 14 | 16 | 19 | 23 | 31 | 38 | 46 |
| 30 | 6.8 | 5 | 12 | 14 | 16 | 19 | 24 | 31 | 39 | 47 |
| 60 | 5.7 | 5 | 14 | 16 | 18 | 22 | 27 | 36 | 44 | 53 |
| 65 | 5.6 | 5 | 14 | 17 | 19 | 22 | 28 | 37 | 46 | 55 |
| 70 | 5.4 | 6 | 15 | 17 | 20 | 23 | 29 | 38 | 47 | 57 |

Table 6 shows the average pupil size after repeated exposure in faint light with respect to the group. The fatigued eye range 31-51-year people are suffering from this fatigue which is approximately 42% reduction of exit pupil size [9]. Table 7 and Table 8shows the minimum magnification in which the pupil-eye size will be a constraint because of normal aperture and existing relaxed pupil-eye size aperture and metrics.

**Table 8**: Metrics

| Inches | 1 | 3 | 3.5 | 4 | 4.75 | 6 | 8 |
|---|---|---|---|---|---|---|---|
| Mm | 25.4 | 76.2 | 88.9 | 101.6 | 120.7 | 152.4 | 203.2 |

## 2.4 LOCALIZATION OF IRIS CENTRE AND EYE CORNERS

For localization of eye corner and iris center, face detection is the first step. By using FARET Database the face detector is designed. In this, the experiment is done by using the face database which includes more than 4000 datasets of facial images from the FARET database and the Internet. The first-row images show the face localization of various poses, face tilted poses, and occlusion of hand. As the eye model shows most of the top and bottom region of the iris region was sheltered by the noises like an eyelid. So the iris is not an intact circle. The integral interval should be limited as the effect of the lid is reduced when the lid shelters the iris partly. For the illusion of the fact that the iris is a circle in shape [43] has used the integral polar coordinate for detecting the centre of the iris in which he provided the integral histogram formula. The $[0, 2\pi]$ is the integral interval in this method. So the iris is not an intact circle. And in which the shelter area may enlarge as the eye blink, frown, gaze at outer and inner eye corner. The integral interval should be limited as the effect of the lid is reduced when the lid shelters the iris partly.

## 2.5 LIVENESS DETECTION USING PUPIL DYNAMICS

The aliveness of the human eye is checked by observing whether the human eye reacts to the light changes or any suspicious presentation like an odd reaction or no reaction. The detection and classification of natural reaction and spontaneous oscillations are done by using linear and non-linear support vector machines which also reject the bad modeling by simultaneous investigation of the goodness of the fit [23]. The process starts with Pupil detection, Segmentation of pupil, and Calculation of the size of the pupil. The change of pupil size is expressed as the pupil dynamics. The pupil could not be detected if the gradient value is not found. Moreover, Complex eye movement patterns [21] are evaluated to determine the acceptable conditions under which to collect viable eye movement data for biometric purposes. The pupil construction and dilations are generated by varying the light intensity. Depending upon the light flash is positive from which the light is negative or darkness to brightness which the pupil responding to the asymmetry [43].

## 2.6 LIVENESS DETECTION USING EYE MOVEMENTS

In eye movement, the liveness detection technique is investigated when a pretender creates a duplicate replica of an eye. The difference between the results of the live or artificial recording was measure with their corresponding classification rate, False Live Rejection (FLR), and False Spoof Acceptance Rate (FSAR) [12]. In the current eye-tracking technology, the system with the resembles of the state-of-the-art system is used for the high-resolution eye-tracking system while the video-oculography technique is used for the low-resolution eye localizing method and the database of EMBD are used in the current iris recognition device with the resembles of hardware found in it [68][69]. For maximizing the classification rate the idea threshold was selected. The principal component analysis is passed by the SVM for obtaining the eigenvector and the utilizing of a multi-dimensional feature vector for both the CEM-B and OPC techniques [12].

## 2.7 TEXTURED CONTACT LENSES IN IRIS RECOGNITION

There are several ways of detecting the textured lens which degrades [22] the accuracy of iris recognition. Segmentation is considered whether the iris is accurately segmented or not for identifying whether the patterned contact lens is present or not. Under various experimental scenarios, the well-constructed database of 8900 images from UBIRIS Version-3 has been constructed for evaluating the contact lens. For the model training, the main database consists of 7000 images, and for the evaluation model, the database consists of 1300 images. The images in the database were acquired from the Iris-Guard AD100 sensor and Iris Access LG4000 sensor in which both the sensors are equally represented. The no lens is the subject without wearing any type of contact lens and finally the textured lens with printing design with an opaque, these lenses are acquired as the image which is altered to the visual appearance to the iris texture area of the eye [13]. 80 different textured lens varieties from the 6000 fake iris images were constructed. When the training is on the heterogeneous data the report says that the correct classification rate is over 98% but when other than these sensors are used for the testing and training set it drops to 87%.

## 2.8 IRIS SEGMENTATION USING ORIENTATION MATCHING TRANSFORM

In iris segmentation, the first step is finding the inner and rough outer iris boundaries by using the algorithm of orientation matching transform which is based on the Edge maps[15] to show the difference among the position characteristics of the iris and the intensity of the iris with eyelashes, eyelid for detecting the noises. For finding the inner and rough outer boundary of the iris the Orientation Matching Transform (OMT) algorithm is used. For the iris segmentation, the Circular Hough Transform (CHT) and edge detection algorithm are used. The process has the modules of colour transform of the iris image then the pupil is detected with the edge detection and the orientation matching algorithm is applied and finally with the Delogne-Kasa Circle fitting.

## 2.9 TRACKING OF EYE USING SMART CAMERA

The tracking and the eye detection algorithm are tested under various conditions which include the head movement speed, different angle of the face, and eye occlusion. In this, the eye-tracking algorithm is used for increasing the accuracy of eye-tracking and after that, the face detection algorithm is performed [18]. The implementation of the function work of the system has been analyzed under changing conditions that analyze the robust algorithm in varying conditions in future work.

## 2.10 SCORE LEVEL FUSION BASED MULTIMODAL BIOMETRICS

In the pattern classification problem, multi-model fusion can be considered as one of them. For the verification task, the input pattern must be labeled as the reject or accept which is considered by the individual expert modalities under the point of view of the given score. In the identification system, the error rate is approximate 50% in the speaker detection module and 42% in the equal error rate of the fingerprint detection module. For the multi-modal identification system, the error rate is 30% which shows the error rate will be reduced to 0% when the score fusion-based multi-model system is in the second rank of the test [19].

# 3. CONCLUSION

This paper has analysed the various modules and techniques of Iris Pattern Recognition with a brief introduction of the anatomy of the human eye, followed by biometrics and Iris recognition. The modules of the review are constrained with how the eye corner and iris centre are detected then the iris strip is made by the extraction of iris even in the eye motions with the removing of unwanted data, in various lighting conditions. The paper also discussed the liveness detection, detection of patterned contact lens, and Methodology for Orientation matching of Iris.

## 4. AVAILABILITY OF DATA AND MATERIAL

Data can be made available by contacting the corresponding author.

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