Iris-Pupil Thickness Based Method for Determining Age Group of a Person

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Abstract: *Soft biometric attributes such as gender, ethnicity and age can be determined from the iris images. Pupil size plays an important factor in iris template aging. In this study, statistical experiments are performed to find out confidence interval for Iris-Pupil thickness of different age groups such as children, youth and senior citizen. Significant group differences have been observed by applying statistical techniques such as Analysis of Variance (ANOVA) and the Tukey's pairwise comparison test. The results of the study conclude that the proposed methodology can be employed to determine age group of a person from the available iris images. Based on the study results, we argue that performance of an iris recognition system can be enhanced by identifying age group of the persons from their iris images.*

Keywords: *Iris recognition, feature extraction, iris aging, iris pupil ratio.*

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1. Introduction

Substantial efforts spanning over a long period have been made by the research community towards guessing approximate age of a human face. Presently, an interesting topic in iris biometric is to resolve or determine age from the iris image. Studies show that with the passage of time, enrolled iris images results in an increase in false non-matching rate [6]. Still sufficient research has not been reported that can help decide age bracket of a person from the available iris image. Age estimation based on snapshot of the eye is relatively more difficult because the tempo at which structure/characteristics of human eye are changed is not very well known. In the establishment of iris biometric research, the research community has somewhat compromised with the earlier findings that iris remains stable throughout the life of a person.

"Template aging" and "Iris aging" are two dissimilar terms, as template aging takes place when enrolled image and verified image match score degrades after lapse of certain time, but with iris aging it means that considerable changes can occur in iris texture pattern as humans grow older [6]. It is generally emphasized that significant features of an iris do not change and remain stable for many years [9], but there are some other factors that occur in the eye structure in old age. Some of these important factors include:

- Pupil Size: Decreases linearly in healthy adults [12]. Pupil dilation decreases with age and consequently hamming distance among the pupil sizes of a person obtained at different stages of life slightly decreases [5]. In this regard, younger people exhibit greater pupil dilation than elderly people.
- Ptosis (blepharoptosis): Drooping of eyelids occurs during the old age. The drooping eyelid can cover all or part of the pupil and results in interference with the vision. Hence, the Euclidian distance between upper and lower eyelid would be lesser in the elderly people as compared to the children and youth.
- Corneal Shape: Fenker *et al.* [8] state that at younger age, cornea tends to have greater curvature along the horizontal axis than the vertical axis. Also, the distance from corneal surface to the iris also changes during the younger age. Eye wrinkles and skin sags result in dull eye color. Due to this, less sclera is visible in old age and eyes do not remain as round, open and wider as it is used to be in the younger people.
- Arcus Senilis: A white or grey arc/ring appears in elderly adults around the outer part of the cornea. People living in different environments can have different iris ageing factors which needs to be further investigated to decide upon choosing it as a candidate attribute for iris recognition research [2, 3].

The rest of this paper is organized as follows: Section 2 provides a related work, an overview of template aging and image dataset. Section 3 describes the problem statement and the research methodology adopted for conducting this research. Section 4 presents the experimental results and details of the statistical analysis performed on the datasets. Finally, sections 5 and 6 summarize the discussion and conclusion respectively.

2. Related Works

Fenker and Bowyer [6] used dataset having three year span between acquisition and verification of images based on four matchers i.e., Iris Bee, VeriEye and two commercial matcher. For this purpose, 285 million comparisons were investigated because of all-vs-all experiments with each matcher. VeriEye proved to be the best among four matchers. Fenker and Bowyer [6] took small time lapse match between two images which belonged to the same year and long time lapse match between images belonging to different years. Ortiz *et al*. [12] propose a linear regression model to explore pupil dilation in terms of age and match scores. VeriEye and IrisBee software are used to produce match data. The authors then compare results of medical literature to determine how pupil size changes with age and conclude that measureable effect in pupil dilation has been observed due to age for actual match assessment.

Fairhurst and Erbilek [5] investigate the effect of physical ageing on performance of iris recognition system by analyzing multiple aspects such as image quality level, improved segmentation algorithm, degree of pupil dilation and dividing age groups into different categories. Quality levels are achieved by dividing available sample images into three groups: Good, poor and bad. Good images are properly segmented, poor and bad images are imperfectly segmented due to noise and small iris region.

Fenker *et al.* [8] discussed methods to eliminate template aging and proposed that multiple iris images should be stored with different dilation value means. Another way is to utilize those sensors that control dilation value. To reduce template aging both aspects (i.e., algorithm for matching templates and sensor use for image acquisition) should be focused. Sgroi *et al.* [14] investigated a classification technique which categorizes person as younger or older with the help of iris texture. Lagree and Bowyer [10] used texture feature that are similar to those used by the researchers for prediction of gender and ethnicity. Proposed work provides the preliminary study in age prediction from iris texture images.

Fenker and Bowyer [7] report that average pupil dilation changes over time which ultimately results in changing the iris texture; and as an enrollment time passes, it increases non false match. Proposed work about template aging is different from other contemporary research as it uses large datasets. Also, pupil dilation and contact lenses factors have been handled by creating data subsets and the same is tested using Iris Bee and VeriEye algorithms. Finally, the authors report that evidence of template aging is noticeable at one year and it increases as time elapses. Czajka [4] analyzed iris template ageing with three different iris matchers VeriEye, MIRLIN SDK and Biometric Iris SDK on the database having eight years long historical image. This is the only worldwide database with such a long time distance between captured sessions. The authors evaluated short term interval to two years versus long term assessment from five to nine years and concluded that short term comparisons demonstrated improved match.

Abbasi *et al.* [1] critically evaluated iris biometric identification and verification methods. The authors notified that accuracy and performance can be achieved by eliminating inferiority images and using only the quality images and discussed that iris segmentation is a challenging task for off angle images especially noisy and blur images. Iris can be divided into numerous regions and verification of single region can identify individuals. Iris biometrics can be applied to identify soft biometric attributes of an individual such as gender, ethnicity and age group.

Ziauddin and Dailey [15] proposed a hybrid technique to localize pupil and iris region. Pupil segmentation is done by first establishing an intensity value by acquiring most of the pupil region, and then a point inside the pupil is calculated to get its radius. The radius point is moved in all the four directions to get background pixels and estimate the final radius. For iris segmentation, relevant region is smoothed by Gaussian filter first and then vertical edges are obtained by performing canny edge map. Horizontal edges are ignored as these edges mostly contain noise due to eyelid and eyelashes. Lastly, the circular Hough transform is applied to get the final iris circle. In [11], biometric data manipulation techniques have also been explored for intrinsic authentication of multimedia objects. A critical review of the template aging techniques reported in the contemporary literature is shown in Table 1.

Table 1. Summary of template ageing techniques

Ref	Area Focus	Technique Used	Strength	Weakness
[12]	Template ageing based on pupil dilation.	Used linear regression model to analysis pupil dilation with age as well as dilation difference.	Analyzed behavior of the match score and variation in pupil dilation.	Focused single factor, focusing on various factors can give more insight
[5]	Experiment pupil dilation effect on performance of system.	Divided age into three groups less than 25, greater than 25 and less than 60, greater than 60. Improved segmentation algorithm to analyze physical ageing	Proposed segmentation algorithm achieves accuracy 99.53 on bio secure database.	Investigate effect on short time lapse (2 years).
[8]	Approaches controlling template ageing are explained.	Three year time lapse dataset.	Discuss several factors contributing eye ageing, found FNMR increases with long time lapse.	-
[14]	Old and young age group identification from Iris texture	Dataset evenly split for younger and orderly group. Random forest algorithm has been used.	Old and young age group is identified with accuracy 64%.	Less accuracy level achieved.
[10]	Ethnicity and gender prediction based on iris texture.	Six filters are used to create feature vector. Mainly are spot and line detector, thick horizontal line, thin horizontal line, thick vertical lined and thin lines.	Achieved 62 % accuracy in gender prediction with mixed ethnicity.	No considerable dissimilarity achieved with single ethnicity.
[7]	Investigated template ageing based on pupil dilation and contact lenses.	2 year time lapse dataset is used; difference in pupil dilation is examined.	Explored various factors to check possibility of template ageing like dependent and independent of pupil dilation.	Study does not give defined estimate between elapsed time and template aging.
[4]	Evaluated inter- and intra-session iris matching	Eight year time lapse dataset is used. Short term as well as Long term comparison is performed.	Matching comparison is performed with large time lapse dataset.	-

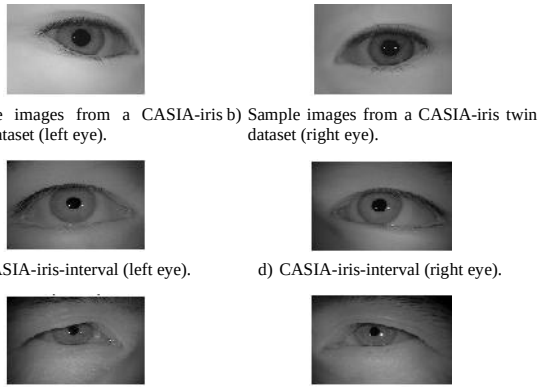
Survey of the contemporary literature and the critical analysis of the iris recognition techniques revealed that lesser work has been done in the area of iris-based age group identification. The same lead as a motivation to conduct this research that focuses on finding Iris-Pupil ratios to establish iris-based age group.

3. Framework Based on Iris-Pupil Ratio

In this section, we discuss our framework to determine age group of a person based on the Iris-Pupil ratio. The idea is to observe the significant differences among these ratios, and based on these differences, we can guess age group bracket of a person with certain degree of likelihood.

3.1. Image Dataset

For performing necessary experimentations, we used three publicly available CASIA version 4.0 datasets namely CASIA-Iris-Twins, CASIA-Iris-Interval and CASIA-Iris-Thousands. CASIA-Iris-Twins dataset mainly consists of twins children who participated in Beijing Festival. CASIA-Iris-Interval dataset mostly consists of CASIA graduate students. CASIA-Iris-thousands dataset consists of wide-range distribution of people of different age groups including students, farmers and workers. Overall 180 images were selected from three datasets; four images (two for left and two for right eyes) for each subject were selected, thus making a total of 60 images from each dataset. Figure 1 shows sample iris images.



a) Sample images from a CASIA-iris twin dataset (left eye).
b) Sample images from a CASIA-iris twin dataset (right eye).
c) CASIA-iris-interval (left eye).
d) CASIA-iris-interval (right eye).
e) CASIA-iris-thousands dataset (left eye).
f) CASIA-iris-thousands dataset (right eye).

Figure 1. Example left and right eye images.

3.2. Research Methodology

In this study, we compartmentalized age groups into three categories: Children, youth and senior citizen (i.e., elderly people). To study dissimilarity of iris image among the different age groups, we took three datasets that fit into each group. As stated earlier, CASIA-iris-twin mostly contains iris images of children; CASIA-iris-interval was the right choice for youth group and CASIA-Iris-thousands caters for irises of all age groups. The irises which do not belong to the children and the youth group were considered as irises of senior citizen group.

We performed a series of experiments on an important aging factor i.e., pupil size. We found iris pupil ratio of all the images to see if there is a significant difference among images of different age groups. Off angle (in which iris was not clearly visible) images were not included in experimentation and only those images were selected in which gaze used to lie in the center location.

Figure 2 shows flow of our proposed template aging prediction algorithm based on pupil size. Our proposed algorithm consists of three main components i.e., iris segmentation, iris pupil ratio and Analysis of Variance (ANOVA) statistical analysis. Iris segmentation was performed by using circular ROI crop algorithm [13] which is primarily based on two points; first point pertains to center of the circle and second point is an estimated radius of the circle. For calculating iris radius of the drooping eyelid, second point was used as an estimate visible point, and crop image was judged until the accurate radius was found. After the iris segmentation, Matlab "imtool" function was used to calculate radius of iris and pupil size against each image. Some images of the elderly person did not show complete iris due to dropping of upper eye lid as shown in Figures 1-e and f. After initial exploration of the dataset, we plotted chart of pupil iris radius ratio for each dataset to see how data visualization plot looks like. Afterwards, we performed a detail statistical analysis for determining confidence interval for each age group.

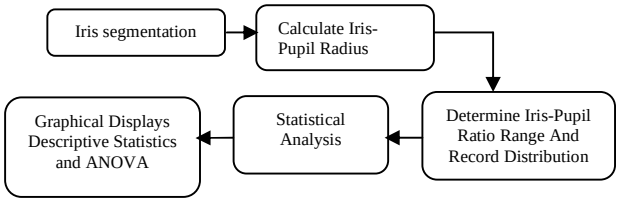


Figure 2. Flow diagram of proposed templates aging prediction based on pupil size.

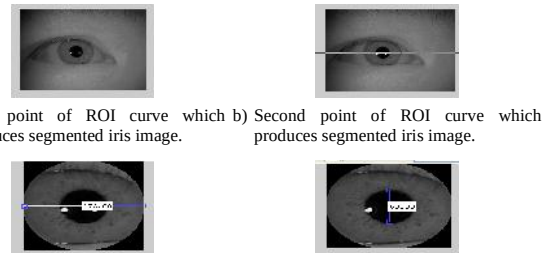
3.3. Segmentation

We performed the following three steps for image segmentation. Figure 3 shows the eye image for which we are going to explain these image segmentation steps.

Figure 3. Sample eye images for which we segment the iris and calculate radius.

- *Step* 1: Read Image: image= imread (abc.jpg).

- *Step* 2: Perform ROI Curve algorithm
  a. ROI= Roicirclecrop (image).
  b. Calculate center point as shown in Figure 4-a.
  c. Calculate estimated radius point as shown in Figure 4-b.
  d. Algorithm returns the segmented iris as shown in Figure 4-c.
- *Step* 3: Use "imtool" function to calculate diameter of Iris as shown in Figure 4-d.
  a. Imtool (ROI).
  b. Radius= Diameter/2.



a) First point of ROI curve which produces segmented iris image.
b) Second point of ROI curve which produces segmented iris image.
c) Image 1 shows the diameter calculation using Matlab "imtool".
d) Image 2 shows the diameter calculation using Matlab "imtool" .

Figure 4. Image segmentation and radius calculation.

4. Experimental Result

We evaluated three iris dataset images in order to select best possible results for template aging. The experimental results showed that pupil-iris ratio was significantly greater for the images of older persons.

In Figure 5, the plotted chart of children age group shows that Iris-Pupil thickness ratios of all the images lie between 2.0 to 3.0. Iris-Pupil thickness ratios for iris images of youth group and senior citizen group lie between 2.0 to 3.5 and 2.5 to 4.5. The visual plot leads us to conclude that pupil size plays an important role in iris aging. Iris-Pupil ratio of all age group is somewhat separated and a clear separation between children and senior datasets is noticeable.

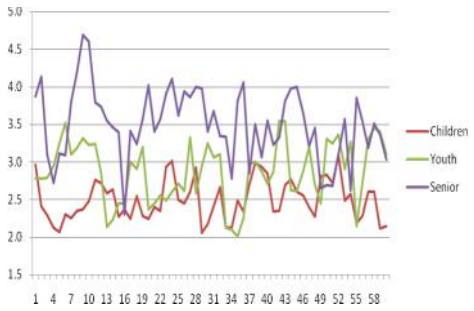


Figure 5. Visual plot showing Iris-Pupil ratios of three datasets.

When we compared all these datasets, we found a clear difference among the images of different age groups as shown in Figure 5.

4.1. Age Group Ratio Range Estimation

After observing dissimilarity between different datasets in the initial experimentation results, we partition Iris-Pupil ratio into six ranges as shown in Table 2. The total number of subjects corresponding to the three age groups employed in this study within the range of 5 intervals (class width) for the entire dataset is shown in Figure 6. Frequency distribution w.r.t. different age group ranges is shown in Table 2.

Table 2. Frequency distribution w.r.t. different age group ranges.

Range	Children	Youth	Senior
2.0-2.4	50%	17%	2%
2.5-2.9	43%	40%	12%
3.0-3.4	7%	37%	30%
3.5-3.9	0%	7%	38%
4.0-4.4	0%	0%	15%
4.5-4.9	0%	0%	3%

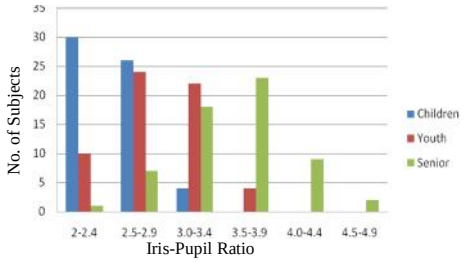


Figure 6. Iris-Pupil ratio w.r.t. number of subjects. It is clear that ratio for senior citizen group lies between 4.0-4.9.

4.2. Statistical Analysis on Iris Data using Boxplots

As mentioned earlier, we evaluated three iris image datasets in order to identify age group of an individual based on the Iris-Pupil ratio. Figure 7 illustrates comparison of the distribution of iris images for the three age groups using boxplots. The boxplots give us an understandable indication of the range, median and quartiles of the distribution of iris images for children, youth and senior citizen age groups. We can observe that Iris-Pupil ratio for the children group is lower than the youth age group, which in return is lesser than the senior citizen age group. Moreover, Table 3 provides summary statistics and the 95% confidence intervals for the mean level of Iris-Pupil ratio for the three age groups.

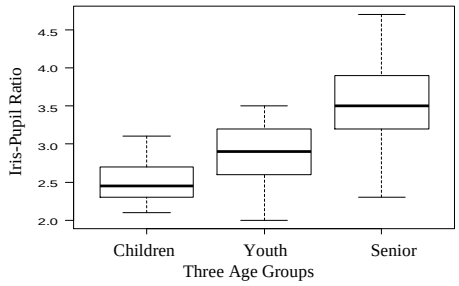


Figure 7. Boxplot of the Iris-Pupil ratio for three age groups.

Table 3. Confidence Intervals for mean value of Iris-Pupil ratio.

Group	No. of Samples	Mean	SD	Confidence Interval
Children	60	2.498	0.271	(2.428, 2.568)
Youth	60	2.868	0.405	(2.764, 2.973)
Senior	60	3.5	0.49	(3.373, 3.627)

Table 3 indicates that:

- We can be 95% confident that the true mean of Iris-Pupil ratio for the children age group is between 2.428 and 2.568.
- We can be 95% confident that the true mean of Iris-Pupil ratio for the youth age group lies between 2.764 and 2.973.
- We can be 95% confident that the true mean of Iris-Pupil ratio for the senior citizen age group lies between 3.373 and 3.627.

4.3. One Way ANOVA Results

We can rely on formal statistical tests/techniques to check whether differences in the three groups are statistically significant from each other. Since, we have three groups to compare; an appropriate method to compare the mean level for more than two groups is the ANOVA method. ANOVA computes ratio of the variation between sample means and the variation within the samples. The higher level of this ratio implies that there exist significant differences among the group means. We performed ANOVA in a statistical software *Minitab ver 16.* The null and alternative hypotheses for the ANOVA are given as under:

$$H0=\mu_{Children=}\ \mu_{youth=}\mu_{Senior}$$

H_1: *At least one pair of the means is different*

Where $\mu_{Children}$, μ_{youth}, and μ_{Senior} represent the true mean of the Iris-Pupil ratio for the children, youth and senior citizen age groups respectively. The core purpose of applying ANOVA test is to see whether the mean levels of the three Iris-Pupil ratio groups differ significantly or not. This will help us in identifying the age group of an individual based on the Iris-Pupil ratio. The results of this analysis are shown in Table 4.

Table 4. ANOVA for Iris-Pupil ratios.

ANOVA for IRIS					
Source	**DF**	**SS**	**MS**	**F**	**P**
Age Group	2	30.785	15.392	96.61	0.000
Error	177	28.200	0.159		
Total	179	58.984			

Where DF represents the degrees of freedom, SS pertains to sum of squares, MS is the mean square, F represents the ratio of the variances that follows the F-distribution and finally P is the probability value. Based on the results shown in Table 4, the probability value (P)=0.000<0.05 (5% significance level) means that we have a strong evidence against the null hypothesis as there exists a significant difference among the mean levels of the three age groups at 5% significance level.

4.4. Tukey's Pair Wise Comparisons

Although, ANOVA tells us that significant differences exist between the three groups, but it does not give us precise information regarding which of the group means are significantly different. For this purpose, we used Turkey's pair wise comparison tests. The Turkey's pair wise method is based on applying the well-known *t*-test on each pair of group means by separately taking into account that the overall significance level remains the same (5% for this study). For example, we have three age group means to compare; therefore, t-test is applied on the all the possible combination pairs of group means i.e., comparing $\mu_{Children}$ with μ_{youth}, comparing $\mu_{Children}$ with μ_{Senior} and finally comparing μ_{youth} with μ_{Senior}. The t-test tells us exactly which of the group mean is different from the other. Furthermore, confidence intervals for the differences among the age groups are also provided. It also gives an indication of the significant differences between the group means. The results for the Turkey's pair wise comparison tests are provided in Table 5.

Table 5. Turkey's pair wise comparison results.

Family Error Rate=0.0500 Individual Error Rate=0.0192 95% Confidence Intervals for (column level mean)–(row level mean)		
	Children	**Youth**
Youth	-0.5421	-
	-0.1979	-
Senior	-1.1738	-0.8038
	-0.8296	-0.4596

Pair wise comparison tests indicate that all the three groups are having statistically significant differences among each other as zero (for no difference) is not included in any of the three confidence intervals. It shows that:

- We can be 95% confident that the mean Iris-Pupil ratio for youth age group is higher than the children age group by 0.198 to 0.542.
- We can be 95% confident that the mean Iris-Pupil ratio for senior citizen age group is higher than the children age group by 0.830 to 1.174.
- We can be 95% confident that the mean Iris-Pupil ratio for senior citizen age group is higher than the youth age group by 0.459 to 0.804.

5. Discussion

In this paper, we presented an algorithm to identify one of three age groups (i.e., children, youth and senior citizen) based on the iris image of a person. The algorithm is based on theoretically simple but very dominant statistical analysis. We determined that iris images can also be used to classify the age group of a person. We performed different statistical analysis techniques such as: ANOVA and boxplot to test our data. Our experimental results support the ones reported by Fairhurst and Erbilek [5]. Fairhurst and

Erbilek [5] divided age into three groups: Less than 25, between 25 and 60 both inclusive and greater than 60. The study results show that there is a significant difference in >60 age group database than the other two groups. Our proposed algorithm also discovered the considerable dissimilarity between senior citizen, children and youth age groups. Whereas, Fenker and Bowyer [6] determine template ageing having three years time interval and Czajka [4] determine template ageing having up to eight years time differences. Until now, Czajka [4] database is considered to be the lengthier elapsed time database between the captured sessions. Due to the unique feature of this database, Czajka [4] evaluated short term interval versus long term assessment. Short term interval consists of two year and long term intervals consist of five to nine years. After the assessment, it is concluded that short term interval proves more match and found increased false non-match rate; it means that as time passes between captured images, system returns non-match.

Ortiz *et al*. [12] inspected template ageing effect in the presence of contact lenses and concluded that contact lenses degrades match quality. It is not usual to enroll the iris template after some elapsed time interval; we already have many identification systems which perform reenrollment such as national identity card, passport and driving license. Instead of using elapsed time, our framework is primarily based on the Iris-Pupil ratio. Our algorithm only divides an individual age into three groups due to the limitation of publicly available datasets. Iris pupil radius is determined using Matlab "imtool" function which possibly appends a bit of human error. In the future research, we intend to diminish this error and also explore additional age groups by using appropriate datasets. This study showed that pupil size can be used as a key factor in template aging.

6. Conclusions

In this study, we found that Iris-Pupil ratio contributes in template aging and experimental results proved the concept. Confidence intervals and statistical tests indicated that significant differences lie between all age groups. Overall, the Iris-Pupil ratio came out to be significantly lower than the youth age group which in return is significantly smaller than the senior citizen group. As a future dimension to this work, we intend to investigate a lesser range of age groups (e.g., infant, toddler, kids, teenager, young adult, middle aged person and senior citizen) as well as other factors that possibly contribute in template aging. Environmental conditions affecting iris ageing will also be explored.

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