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Iris Image Quality Testing and Iris Verification

Lidong Wang
Department of Applied Technology, Mississippi Valley State University

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ABSTRACT

The purpose of this study was to investigate the iris image quality and iris verification of eyes in brown, hazel, green, and blue, respectively, and the iris image quality and iris verification under different conditions such as the changed stand-off distances, the motions of the head and eyes, with glasses, and without glasses. A comparative study of three eye colors in brown, hazel, and green was conducted using a non-parametric method based on the *H* test. The *H* test results show that there is no significant difference in the iris image quality of eyes in brown, hazel, or green when the level of significance is 0.05.

Corresponding Author:

Lidong Wang,
Department of Applied Technology,
Mississippi Valley State University,
14000 Hwy, 82 West, Itta Bena, Mississippi 38941, USA.
Email: lwang22@students.tntech.edu

1. INTRODUCTION

Iris recognition is a process that analyses the features (such as rings, furrows, and freckles) that exist in the coloured tissue surrounding the pupil. There are little aging effects made to iris patterns after the age of two. Most eye surgeries rarely affect the iris. Fine iris texture can keep remarkably stable over life from age two until death. Therefore, iris re-enrolment is not required and previously registered iris data can be used continuously. Iris recognition can be used in immigration systems, border security systems, national identity cards, identity management and e-Governance, and aviation security and access control for restricted areas at airports, etc. [1], [2].

Iris recognition continues to be acknowledged as the most accurate biometric recognition method available in the world today (more accurate than DNA matching). However, the performance of the iris systems can be affected by iris images with poor quality. Iris image quality assessment can be made by analyzing the effects of seven quality factors: defocus blur, motion blur, off-angle, occlusion, specular reflection, lighting, and pixel counts on the performance of traditional iris recognition system. Defocus blur, motion blur, and off-angle are the factors that most affect recognition performance [3].

Some of the main parameters that specify an image system are its resolution, depth of field (DOF), field of view, and exposure period per image-frame. The field of view determines the spatial extent of the scene acquired by the sensor. Depth of field determines how far a planar object can move away from the best focus position and still be imaged without focus errors. Current iris recognition systems suffer from limited depth of field, which makes it somewhat difficult for an untrained user to use these systems. Traditionally, the depth of field is increased by reducing the image system aperture, which adversely impacts the light capturing power and thus the system signal-to noise ratio (SNR) [4].

Iris recognition systems still need to improve their accuracy in environments characterized by unfavorable lighting, large stand-off distances, and moving subjects [5]. The stand-off distance is the distance from the camera to the subject or the user of the iris recognition system. Researchers must solve issues such as capturing eye images of sufficient quality in less than ideal conditions and accurately localizing the iris's spatial extent in poor-quality images. Recent efforts have successfully designed and developed iris-on-the-move and iris-at-a-distance recognition systems [5]. An iris recognition system at a distance of about three meters was developed [6]. A new image acquisition system called BIris On the Move was developed to reduce constraints in position and motion. This new system uses high-resolution cameras, video synchronized strobe illumination, and specularity-based image segmentation. It has resulted in an increased capture volume, decreased acquisition time, increased stand-off distance, and the ability to acquire iris images from moving subjects [7].

The purpose of this paper is to study: 1) iris image quality and iris verification for four kinds of eyes (brown, hazel, green, and blue); 2) iris image quality and iris verification under different conditions, such as the changed stand-off distances, the motions of the head and eyes, with or without glasses; 3) a non-parametric analysis based on the *H* test for three kinds of eyes (brown, hazel, and green) to study their difference.

2. IRIS IMAGE QUALITY AND IRIS VERIFICATION IN DIFFERENT SITUATIONS

2.1. The Experimental Method and the Experimental System

IrisAccess™ 4000, an iris recognition system developed by LG Electronics, was used in this study. The LG IrisAccess™ iData EAC Software v 3.00.14 was installed in the iris system. The camera iCAM4000 was used to acquire the subjects' iris images. The iCAM4000 is a two-eye iris camera which includes an alignment indicator behind the mirror and voice prompts to assist the user. It can be used in enrollment and verification. The IrisAccess™ 4000 system has five function modules: IrisServer, IrisEnroll, IrisManager, IrisMonitor, and IrisDBAdmin. Only administrators may login in IrisServer; IrisServer must be running before starting IrisEnroll. IrisEnroll is used to enroll the irises of users into the system, and for the identification or verification of the users; IrisEnroll must first be registered in IrisManager. IrisManager is used to manage the Users, Operators (administrator-level only), Remote Units, Programs, and Groups, as well as Report generation in the system. IrisMonitor is used to monitor the IrisAccess™ 4000 system. IrisDBAdmin is a database administration tool; this tool facilitates an easier manipulation for backup, import, create, drop, upgrade, and manage in the IrisServer database for the database administrator. The iris system can be used in enrollment and verification. Enrollment is the process of adding new records. The records are used to validate the users' identity during the verification process. The user can perform a verification test by clicking on the Verification Test button. The system can also perform fake eye detection. The fake eye detection increases the time required for enrollment, identification, or verification, but greatly enhances the security of the system. The iris system can prompt the user to present his/her iris to the camera. The system will prompt for another try if the results of the image processing are not of good quality. Another prompt will also appear if the image was not captured properly on the second try. There is a maximum of three attempts for image processing. If the user does not succeed in the third attempt, he or she will be asked to begin again by selecting the Enroll icon from the start menu [8], [9].

Iris images are displayed on the Main window of the sever PC; the quality of the IrisCode created is displayed in the Processing Result window as soon as iris scanning is completed. The processing result is the iris quality score. The quality score ranges from 0 to 100. The lowest value is fixed at 0 and the highest value is fixed at 100. To obtain iris images with a higher quality and decrease the "False Reject Rate" (FRR: the rejection rate of an iris that should be accepted), the user should follow the recommendations below [9]:

1) The user should keep both eyes wide open and look into the rectangular mirror aligning the colored dot between the eyes until the audio message of "We finish taking pictures of your eyes" plays.
2) The user should not rotate, pan, or tilt his/her face.
3) Eye glasses must be removed before enrollment, but may be worn during verification or identification.
4) Contact lenses with patterns that cover any part of the iris cannot be worn.

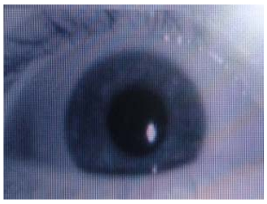
2.2. Iris Images, Image Quality Scores and Iris Verification for Different Eye Colors

Four test subjects' iris images were captured using the IrisAccess™ 4000 system in the Automated Identification Technology lab at Mississippi Valley State University, USA. The four test subjects had brown, hazel, green, and blue eyes, respectively. None of them wore glasses. The stand-off distance from the camera to the individual was 20 cm. Figure 1 shows the four individuals' iris images and the image quality scores after the enrollment process. The iris image acquisition yielded images of the irises and the surrounding eye regions. All of the four images were used for the each individual verification and the verifications were successful, although Figure 1 (a) and Figure 1 (d) are images with occlusion and relatively low quality scores.


(a)


(b)


(c)


(d)

(a) African American; Male; Eye color: Brown; Image with occlusion; Quality score—86.4
(b) Caucasian; Female; Eye color: Hazel; Quality score—98.6
(c) Caucasian; Male; Eye color: Green; Quality score—93.4
(d) Caucasian; Female; Eye color: Blue; Image with occlusion; Quality score—89.6

Figure 1. Iris images and image quality scores for four people without glasses

2.3. Iris Images, Image Quality Scores and Iris Verification under Changed Conditions

Figure 2 shows a Chinese male's brown iris images and quality scores of the iris enrollment with and without glasses. The stand-off distance from the camera to the individual was 20 cm. Figure 2 indicates that there was a light reflection due to his glasses; the iris quality score decreased. The two images were used for verification and each was successful, although Figure 2 (b) is an occluded image with the light reflection and a lower quality score.


(a)


(b)

(a) Without glasses; Image with occlusion; Quality score—92.6
(b) With glasses; Image with occlusion; Quality score—82.2

Figure 2. Comparison of a Chinese male's brown iris images and image quality scores

Glasses, sunglasses, and contact lenses can affect the iris image quality and performance of the iris system. Previous research demonstrated that there were different degradations in performance for different types of contact lenses and that lenses producing larger artifacts on the iris yielded more degraded performance [10]. Three people were tested when they wore glasses and when they did not wear glasses using the IrisAccess™ 4000 system. The stand-off distance was still 20 cm. Table 1 lists the iris testing results, including the iris image quality scores of the enrollment and verification outcomes under different conditions during the iris enrollment (with/without glasses) and the iris verification (with/without glasses). Because the verification was conducted right after the enrollment process (almost at the same time), the iris image score during the verification was regarded as almost the same as the score during the enrollment. Table 1 indicates that glasses can decrease the iris image quality scores and sunglasses can lead to verification failure. The literature [9] recommends that eye glasses must be removed before enrollment; however, glasses did not affect the success in iris verification although the iris image scores decreased (see the results in Table

1). The IrisAccess^{TM} 4000 system had better performance than expected and as described in the system manuals.

Table 1.
The effects of glasses and sunglasses on iris image (without occlusion) scores and verification outcomes

No	Ethnicity	Gender	Eye colors	Enrollment	Verification	Iris image scores	Verification outcomes
1	African American	Male	Brown	Without glasses	Without glasses	97.8	Success
				With sunglasses	With sunglasses	58.4	Failure
2	Caucasian	Female	Blue	Without glasses	Without glasses	96.6	Success
				With glasses	With glasses	88.4	Success
3	Chinese	Male	Brown	Without glasses	Without glasses	98.6	Success
				With glasses	With glasses	89.8	Success

In previous research, both eye and head positions must be controlled. Head or eye motion during iris scanning can cause image blur. The body can move in three dimensions; both the head and eyes can move independently. Increasing the stability of the body, the head, and the eyes increases the accuracy and performance in iris scanning and iris verification [3], [5]. However, the results in Table 2 indicate that there were no motion-induced effects on iris image scores and that there was success in iris verification when the Chinese male (brown eyes, without glasses) shook his head, nodded, or had eye motion during the enrollment and the verification. The stand-off distance from the camera to the individual was also 20 cm. Table 2 also indicates that the IrisAccess^{TM} 4000 system has better performance than expected and as described in the system manual [9].

Table 2.
The effects of motions on iris image scores

Enrollment	No motion	Head shaking	Nodding	Eye motion
Iris image scores	98.6	98.6	98.6	98.6

Table 3 shows the Chinese male's brown iris image scores under changes in the stand-off distance. The testing results demonstrate that the stand-off distance from 18-25cm is the image capture range of the IrisAccess^{TM} 4000 system and that distance changes within this range do not affect iris image scores.

Table 3.
The effects of changed stand-off distances on iris image scores

Stand-off distances (cm)	17	18	20	22	24	25	26
Iris image quality scores	Cannot capture iris images	98.6	98.6	98.6	98.6	98.6	Cannot capture iris images

Many professionals typically thought that the iris capture process was sensitive to lighting conditions present in the testing room and that no direct or artificial light should directly reflect off the enrollee's eyes [3]. However, after obtaining iris image scores of the enrollment when lights were on and off in the lab, there was almost no difference in iris image scores.

3. RESULTS AND ANALYSIS FOR THREE EYE COLORS

3.1. Data and Descriptive Statistics for Iris Image Quality Scores

In addition to the four subjects tested, twenty eight additional students at the university were invited to participate in iris enrollment and verification tests in November, 2012 to study the difference in iris image quality among three types of eyes in brown, hazel, and green. These students were 18-25 years old. African American students were dominant at the university; Caucasian students were a minority group. Most of the African American students had brown eyes. Among the 28 students, 16 students had brown eyes; seven students had hazel eyes; and five students had green eyes. Although the five and seven meet the requirement [11] for the *H* test, it was expected to find more students with hazel eyes or green eyes.

Table 4 shows a breakdown in ethnicity, gender, eye color, and iris image scores. The Stand-off distance was 20 cm. None of the students wore glasses during the iris enrollment and iris verification. All of the verifications were successful. Table 5 shows the mean μ and the standard deviation σ of the iris image scores for the students with eyes in brown, hazel, and green.

Table 4.
Demographics of the students participated in iris scanning tests and their iris image scores

No	Ethnicity	Gender	Eye color	Iris score
1	African American	Male	Brown	99.0
2	African American	Male	Brown	89.6
3	African American	Male	Brown	98.6
4	African American	Male	Brown	97.9
5	African American	Male	Brown	99.0
6	African American	Male	Brown	98.6
7	African American	Male	Brown	98.6
8	African American	Male	Brown	89.6
9	African American	Female	Brown	89.6
10	African American	Female	Brown	83.5
11	African American	Female	Brown	98.6
12	African American	Female	Brown	98.6
13	Caucasian	Male	Brown	98.6
14	Indian	Male	Brown	98.6
15	Indian	Male	Brown	97.9
16	Chinese	Male	Brown	98.6
17	African American	Male	Hazel	98.6
18	African American	Male	Hazel	97.9
19	African American	Male	Hazel	98.4
20	African American	Female	Hazel	89.7
21	African American	Female	Hazel	98.8
22	African American	Female	Hazel	99.0
23	Caucasian	Female	Hazel	98.6
24	Caucasian	Male	Green	98.6
25	Caucasian	Male	Green	99.0
26	Caucasian	Male	Green	98.4
27	Caucasian	Female	Green	97.9
28	Caucasian	Female	Green	89.8

Table 5.
The mean μ and standard deviation σ of iris image scores for the students in three kinds eye colors

Eye color	Brown	Hazel	Green
μ	95.93	97.29	96.74
σ	4.89	3.36	3.90

3.2. Non-parametric Analysis for the Image Quality of Three Eye Colors

Table 5 shows there is difference in the image quality of the three eye colors (brown, hazel, and green). Professionals are concerned about whether or not there is a significant difference. The *H* test, a non-parametric method, was used to conduct a comparative study among the three eye colors. The *H* test is also called the Kruskal-Wallis test [11]. It is a rank-sum test that is used to test the null hypothesis that *k* independent random samples come from populations with approximately identical means against the alternative hypothesis that the means of the populations are not all equal. The major advantage of non-parametric methods is that they do not require specific assumptions (such as normal distribution or approximate normal distribution) about the sampled populations. Therefore, non-parametric methods can be used under more general conditions.

The data of the samples are ranked jointly from low to high as though they constitute a single sample. If R_i is the sum of the ranks assigned to the n_i values of the *i*th sample and $n = n_1 + n_2 + \cdots + n_k$, the *H* test is based on the following statistic:

$$H = \frac{12}{n(n+1)}\sum_{i=1}^{k}\frac{R_i^2}{n_i} - 3(n+1) \tag{1}$$

If each sample has at least five observations and the calculated *H* is greater than or equal to χ_α^2 [11] for $k-1$ degrees of freedom, the null hypothesis should be rejected and the alternative hypothesis should be accepted. α is the level of significance. The following null hypothesis is formulated:

There is no statistically significant difference in the iris image quality scores of the three kinds of eyes in brown, hazel, and green.

The outcome is: the hypothesis is accepted or rejected at $\alpha = 0.05$.

In this study, *k* = 3; n_1 = 16; n_2 = 7; n_3 = 5; and n = 28. Arranging the data in Table 4 jointly according to size and assigning the data the ranks 1, 2, 3, …, and 28; thus, R_1 = 210.5, R_2 = 119.5, and R_3 = 76. Substituting these values into formula (1), *H* was obtained and *H* = 1.15. χ_α^2 is given in TABLE IV [11]. χ_α^2 = 5.991 for $\alpha = 0.05$ and $3-1$ degrees of freedom. Since the calculated *H* = 1.15 is less than 5.991, the null hypothesis must be accepted; there is no significant difference in the iris image quality scores of eyes in brown, hazel, and green when the level of significance is 0.05.

4. CONCLUSION

Iris images and quality scores for four kinds of eyes (brown, hazel, green, and blue) without glasses were captured through the IrisAccess™ 4000 system and the iris verifications for the four kinds of eyes were successful. The iris verifications with glasses were still successful although glasses can decrease iris image quality scores due to light reflection. Sunglasses can also lead to verification failure.

There were no motion-induced effects on the iris image scores and the success in iris verification when the Chinese male (brown eyes, without glasses) had some head shaking, nodding, and eye motion during the enrollment and verification. The IrisAccess™ 4000 system can capture iris images if the stand-off distance ranges from 18-25cm. Distance changes within this range do not affect iris image scores. There was almost no difference in iris image scores when the lights were on and when the lights were off in the lab. The IrisAccess™ 4000 system has better performance than expected and as described in the system manual.

According to the results obtained from the non-parametric method based on the *H* test, at the 0.05 level of significance, there is no significant difference in the iris image quality of eyes in brown, hazel, and green.

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BIOGRAPHY OF AUTHOR

Dr. Lidong Wang is the Director of the Automated Identification Technology (AIT) Program and an Assistant Professor in the Department of Applied Technology at Mississippi Valley State University, USA. He had conducted research at the University of South Carolina, Ohio State University, and Mississippi State University; and conducted projects supported by the Department of Defense (DOD), the National Science Foundation (NSF), and the National Aeronautics and Space Administration (NASA) before he moved to Mississippi Valley State University in 2007. His current research interests include: biometrics and radio frequency identification (RFID). He has published over 40 papers in various journals.

Dr. Wang has been invited to review papers by over 10 professional journals. He has also been invited by four professional journals to act as their guest editor. He has been the Editor-in-Chief of the International Journal of Automated Identification Technology (IJAIT) for five years.