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Iris recognition as a biometric method after cataract surgery

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Abstract

Background: Biometric methods are security technologies, which use human characteristics for personal identification. Iris recognition systems use iris textures as unique identifiers. This paper presents an analysis of the verification of iris identities after intra-ocular procedures, when individuals were enrolled before the surgery.

Methods: Fifty-five eyes from fifty-five patients had their irises enrolled before a cataract surgery was performed. They had their irises verified three times before and three times after the procedure, and the Hamming (mathematical) distance of each identification trial was determined, in a controlled ideal biometric environment. The mathematical difference between the iris code before and after the surgery was also compared to a subjective evaluation of the iris anatomy alteration by an experienced surgeon.

Results: A correlation between visible subjective iris texture alteration and mathematical difference was verified. We found only six cases in which the eye was no more recognizable, but these eyes were later reenrolled. The main anatomical changes that were found in the new impostor eyes are described.

Conclusions: Cataract surgeries change iris textures in such a way that iris recognition systems, which perform mathematical comparisons of textural biometric features, are able to detect these changes and sometimes even discard a pre-enrolled iris considering it an impostor. In our study, re-enrollment proved to be a feasible procedure.

Background

Biometrics is the automated use of physiological or behavioral characteristics to determine or verify identity. Biometric authentication requires only a few seconds, and biometric systems are able to compare thousands of records per second. Finger-scan, facial-scan, iris-scan, hand-scan and retina-scan are considered physiological biometrics and voice-scan and signature-scan are considered behavioral biometrics. A distinction may be drawn between an individual and an identity; the individual is singular, but he may have more than one identity, for example ten registered fingerprints are viewed as ten different identities [1].

The combinatorial complexity of phase information across different iris textures from persons spans around 249 degrees of freedom and generates discrimination entropy of about 3.2 bits/mm^2 over the iris, enabling decisions about personal identity with extremely high confidence[2]. The extracted feature is the phase characteristic of the picture element in study, related to adjacent ones, in an infrared (not color) iris photograph. This means, for example, that false match probabilities might be as low as one in 10^{74}. False reject rates may be as high as 5–10% depending on ambient conditions, so scientific tests should be done under ideal conditions to minimize chance for errors.

The matching process is as follows: a user initially enrolls in biometric systems by providing biometric data, which are converted into a template. Templates are small archives called "iris codes" (Figure 1), consisting of optimized and filtered biometric acquired images. These templates are stored in biometric systems for the purpose of sub sequential comparison. Then the user presents his biometric data again, and another template is created. The verification template is compared to the enrollment template, and the mathematical difference between the iris codes is computed. This mathematical difference is called the Hamming distance (HD) [4]. In other words, the Hamming distance is the numerical difference between two iris codes. The Hamming distance between identification and enrollment codes is used as a score and is compared to a confidence threshold for a specific equipment or use, giving a match or non-match result. Systems may be highly secure or not secure, depending on their confidence threshold settings.

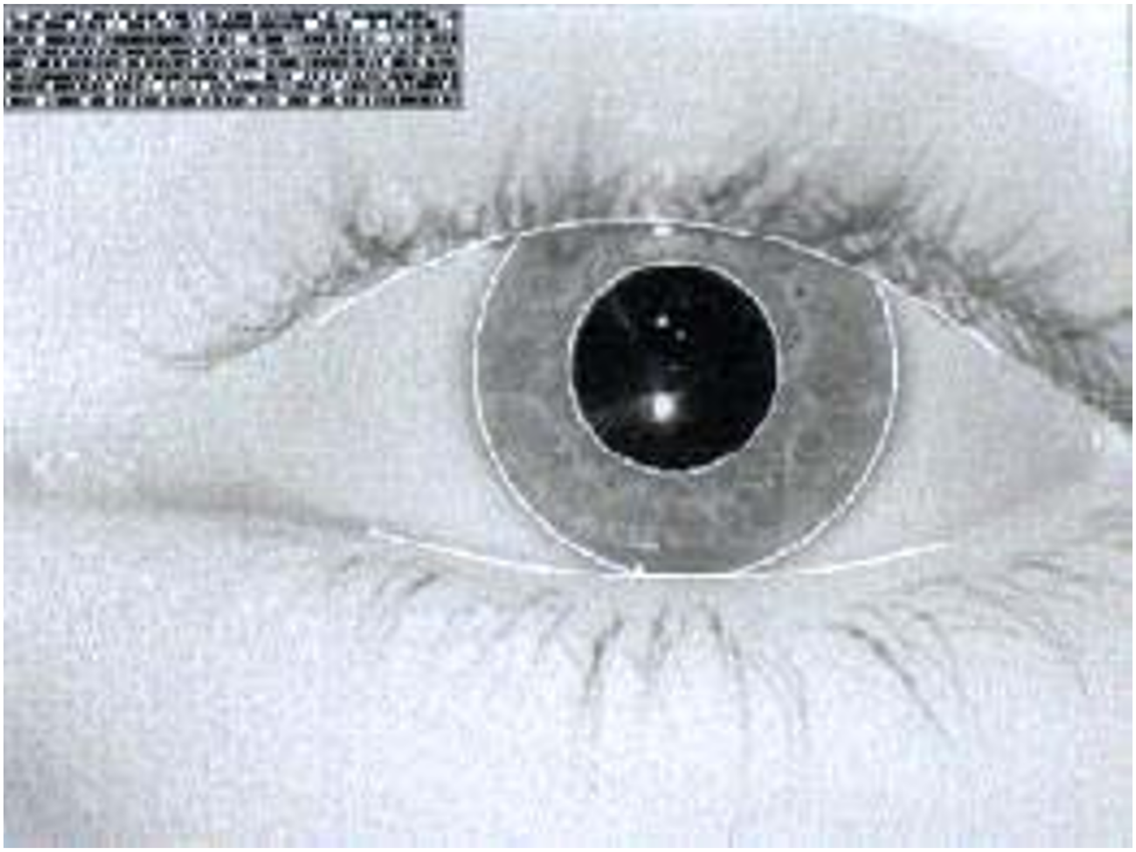

Figure 1
Iris code from an iris-scan. (Adapted from [3] (© 1990 IEEE))

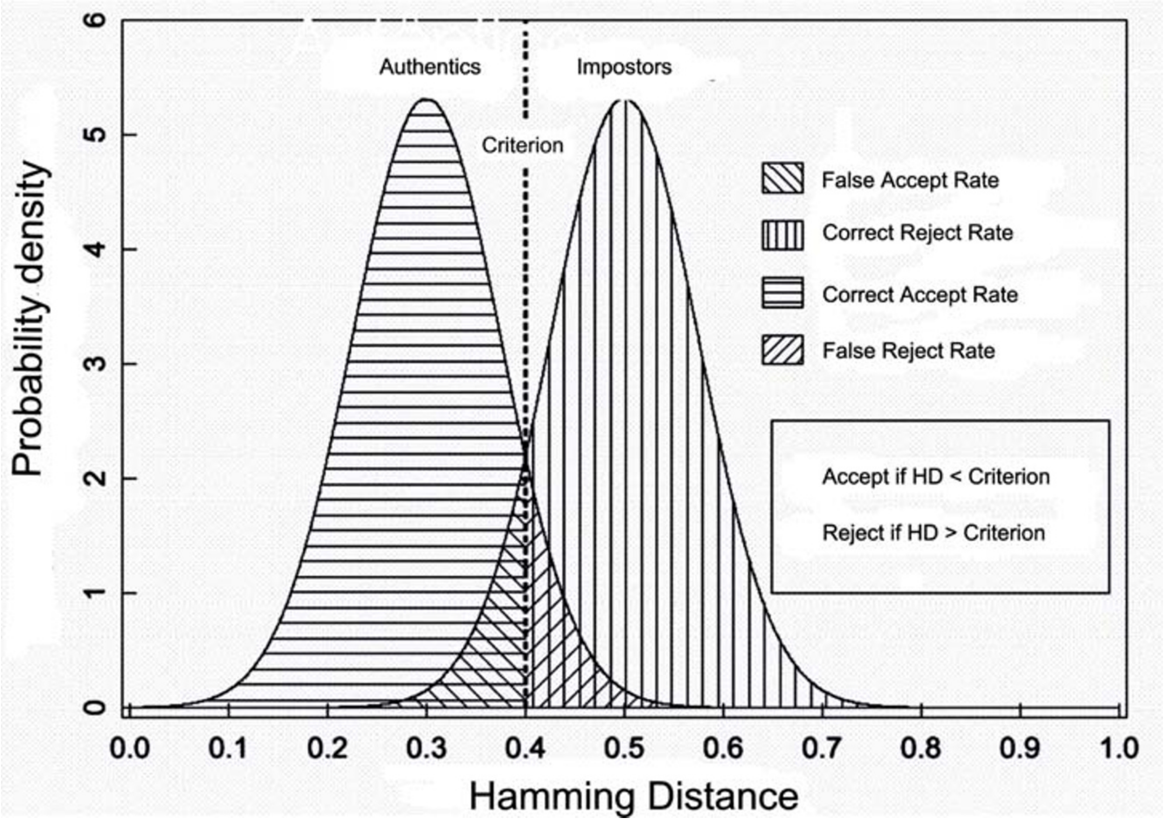

Figure 2
General formalism for biometric decision making (Adapted from [6] (© 1999 IEEE))

Data acquisition begins with reliable means of establishing a visible iris, and then its boundaries are precisely located by a circular edge detector algorithm. Extracting textural characteristics are based in 2-D Gabor phasor coefficients which are computed, providing high orientational and spatial-frequency resolution as well as the information of its 2-D position. Zones of analysis are established on the iris in a projected polar coordinate system, dimensionless, in order to maintain reference to the same regions of the iris regardless of constriction of iris (pupillary size), distance to eye and video zoom factor. Each bit in an iris code can be regarded as a coordinate of a vertice in a unit square of the complex plane from the coordinate system described above, forming a 256 bytes code, which is used for comparisons [5].

The decision made by the algorithm may be either correct or incorrect. The four outcomes, as illustrated above, are consequently a correct accept, false accept, correct reject and false reject. Figure 2 illustrates the idea of a decision environment in a recognition system. The two distributions represent the two statuses, authentic and impostor, which are imperfectly separated. The abscissa is a metric of similarity, the Hamming distance. In this case, a 0.4 HD criterion best separates the two distributions of patterns [6].

Unique templates are generated every time a user presents biometric data, due to changes in positioning, distance, pressure, environment and other factors. Data from real comparisons using iris recognition systems in laboratory conditions (at a single illuminance, with well-informed volunteers) reveal more distant curves, which do not overlap (Figure 3) [5-9].

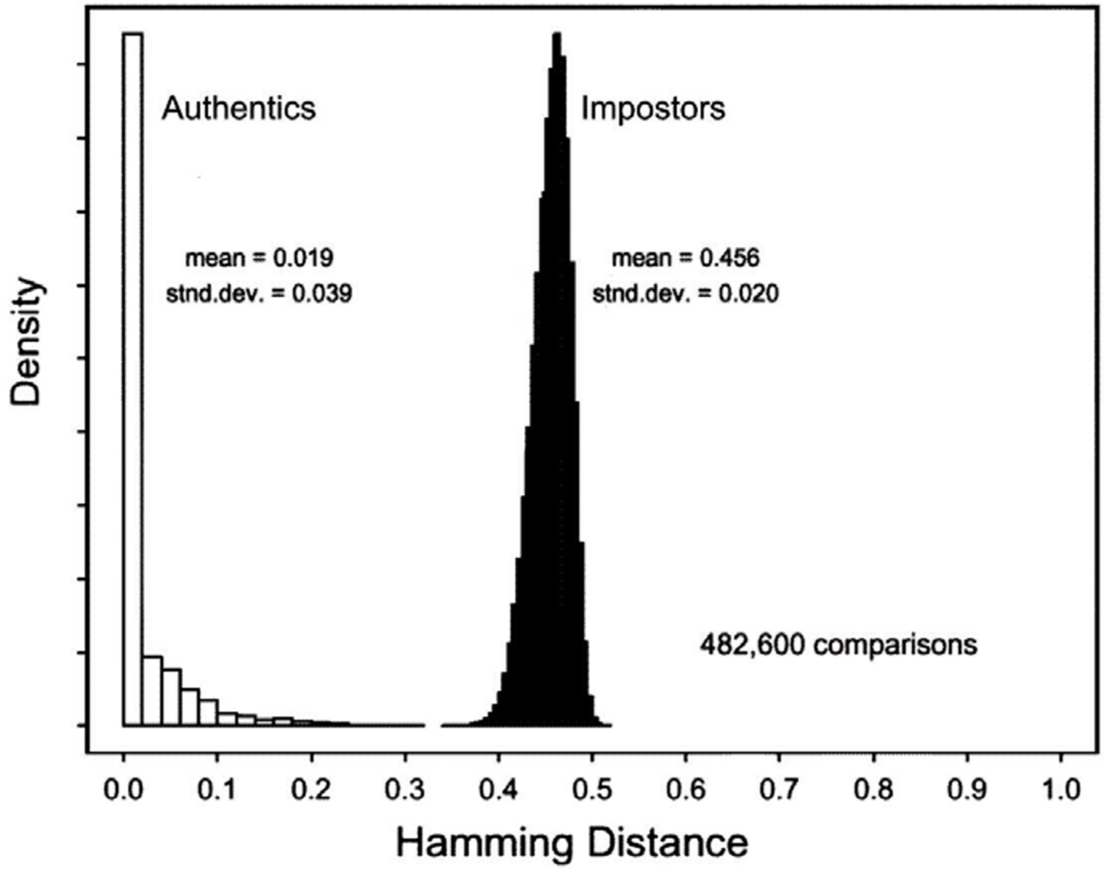

Figure 3
Decision environment for iris recognition under ideal laboratory conditions (Adapted from [5] (© 1993 IEEE))

The equipment is also able to rotate the images and compensate for tilt and pupillary dilation.

There are, to our knowledge, no scientific papers describing medical procedures interfering in biometric data in iris recognition, there are reports in fingerprinting though [10]. The aim of this study was to verify what could happen to recognition capacity when a common intra-ocular procedure such as cataract surgery alters iris texture [11], and what kind of misrecognition could take place.

Methods

We report data from fifty-five patients chosen for cataract surgery performed by second year residents in their first semester of phacoemulsification training. From the 55 patients, 28 right cataractous eyes and 27 left cataractous eyes were selected, although we know an iris from a persons' eye is as much different from the contralateral eye as it is from another persons' [3]. The Iris Recognition System used had its reproducibility validated by the licensees of the algorithms and the equipment used in the study is LG's IrisAccess 2000®. Informed consent was gathered from each patient and the protocol was approved by the ethics committee of the Federal University of São Paulo.

Patients were properly positioned in front of the equipment and maximum ocular opening was instructed. Research was conducted in the same room under constant illuminance (horizontal and vertical 70 lux) and at fixed distance to the equipment, so that ideal laboratory conditions (described in [2]) were accomplished. The iris was separated in four quadrants and these were photographed with a slit lamp-attached Topcon® camera. All patients had never undergone any other ocular surgery and did not have other associated ocular diseases. Enrollment was followed by three identification trials, and Hamming distance and focus data were retrieved. Three trials were not necessary giving the favorable experiment conditions, but sometimes old patients sneeze or cough and move aside from the equipment, so we chose the best trial in three. The patient then underwent the operation. One month after the procedure, and one week after the use of mydriatics was discontinued; each patient was subjected to three identification trials. Pupillary size changes were accounted for in the algorithm, and we describe that none of our patients were dilated and we could not see pupillary size differences larger than 1.5 mm. The major iris changes occur in the first postoperative period due to surgical manipulation, and the acute healing with the chronic tissue retraction are usually complete by one month, hence the testing period length. Hamming distance and focus were retrieved and slit-lamp photographs were taken. At this time, each patient had his or her iris examined in the slit-lamp by an anterior segment specialist, who gave a score for the visible texture alterations. One point was given for each of the following alterations: focal atrophy without transillumination, depigmentation, focal atrophy with transillumination and pupil ovalization. A score of zero represented no visible alterations and a score of four meant all of these visible alterations were present.

The average preoperative Hamming distance was then compared to the average postoperative Hamming distance. The threshold determined for the Hamming distance was 0.4, the same used in most indoors public applications. The Hamming distance difference between the lowest postoperative and preoperative distance was then calculated for each case. The lowest value was chosen because it corresponds to the best image acquisition for coding purposes. The score created for each patient's clinical alterations was then compared to the numeric difference for each case, so that a relationship between clinical visible textural alterations and numeric difference could be established.

The end points of the analysis were assessed with the use of SPSS software; analysis of variance and Students' *t test* were used to test for statistical significance.

Results

All image captures were suitable for optimal image acquisition, with a good focus values over 95% (up to 100% scale, acceptable if over 70%) and image quality values over 1200 (up to 1600 specific scale, acceptable if over 600). In all cases there was a correspondence between maximum ocular opening achieved in the preoperative and postoperative period, as verified in the pictures captured at the moment of iris codes determination.

Six patients were no longer recognized (example at Figure 4) after the procedure, and these eyes were reenrolled creating a new template or iris code. All other patients were still recognized even though they had numerical and clinical alterations.

The average of Hamming distances in the preoperative period was 0.098 and in the postoperative period it was 0.2094; the numeric overall difference is 11.13%.

The patients were divided into three groups for statistical purposes: Scores = zero, Scores = 1 and Scores > 1. For each of these groups the number of patients (n), average difference in Hamming distance (avg) and pattern deviation (pd) were as follows: Score = zero group had n = 13, avg = 0.0696, pd = 0.0604; Score = 1 group had n = 24, avg = 0.0840, pd = 0.0611; Score > 1 group had n = 18, avg = 0.178, pd: 0.120. Using ANOVA for group comparison we found there were statistically significant differences between the groups ($p < 0.001$). There were statistically significant differences between groups Score = 1 and Score > 1 ($p < 0.05$) and Score = 0 and Score > 1 ($p < 0.05$), but no difference between groups Score = 0 and Score = 1($p < 0.05$) (Tukey test).

Discussion

All surgeries were performed by residents in phacoemulsification, under the tutelage of an experienced surgeon. Consequently this study does not intend and does not actually reproduce iris alterations at a rate similar to the usual ophthalmologic practice. All patients in this study had a proper interaction with the system as it was carefully explained how the image capture procedure works and they were cooperative. The mechanism of iris change due to the probe is usually unknown, though it is known that iris tissue can be emulsified when the probe tip is pointed to it and there is progressive atrophy after manipulation; it is speculated that even without any contact with the iris tissue, the energy dissipated in the anterior chamber might be responsible for depigmentation.

The mean Hamming distance changed 11.3% during the study due to the surgical procedure, from 0.098 to 0.2094; in other words, the authentics' curve moved into the threshold direction (and the direction of the impostors' curve) by 11.13%. That move is not big enough for most individuals, who were still recognized.

Repetitive individual iris scanning under non ideal conditions of an unoperated eye should not find differences in more than 10% of the iris code, and usually less than 5%. The mathematical difference association with visible slit-lamp textural alterations indicates that there is a positive association between the procedure and an outside normal iris code variation. It also indicates that we are able to predict cases in which iris recognition systems will have difficulty identifying people based on slit-lamp examinations.

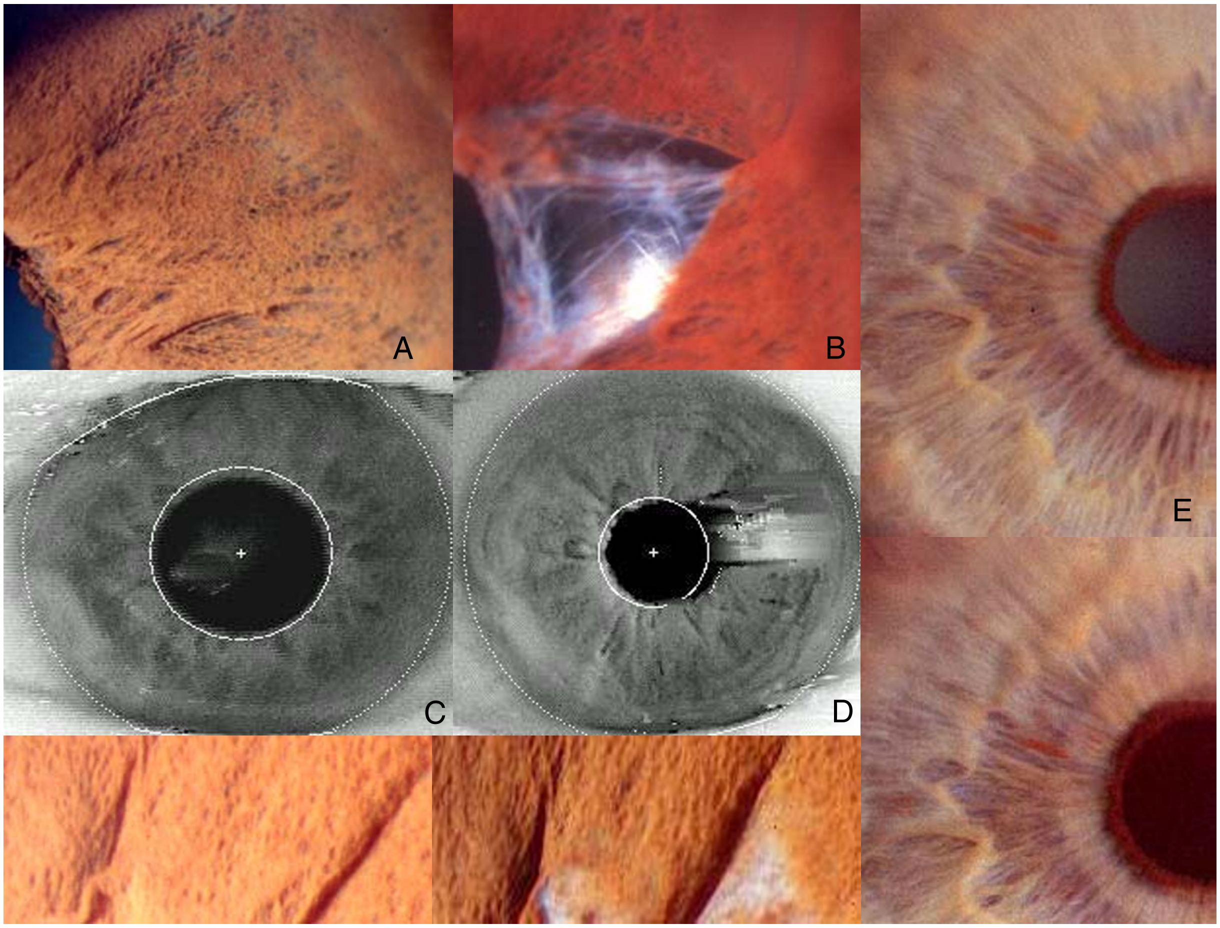

Figure 4

Color and infrared photos of a patient before and after the cataract surgery Same iris, before and after surgery. (A and B) Color photos. (C and D) Infrared photos of subject A and B (E and F) Barely visible changes. Score 0. (G and H) Light depigmentation. Score 1.

The most common iris changes were depigmentation and localized iris atrophy, with loss of large areas of Fuchs' crypts, circular and radial furrows and pupil ovalization. In this study there were no false matches, in other words, no patient was identified as another individual because of his textural changes. To sum up we understand some patients can be identified successfully and others cannot due to the existence of a damage threshold, yet to be determined, which is correlated with the degree of visible changes and we propose the iris biometric reenrollment of all patients submitted to cataract surgery, in order to avoid false negative results in pseudophakic patient iris identification. Iris specific alterations correspondence in the code appears to be one of the probable natural sequences for our research.

Conclusion

Cataract procedures are able to change iris texture in such a way that iris pattern recognition is no longer feasible or the probability of false rejected subjects is increased. Patients who are subjected to intraocular procedures may be advised to reenroll in biometric iris systems which use this particular algorithm so as to have a new template in the database.

Authors' contributions

RR carried out the iris analysis and drafted the manuscript. PS conceived the sequential idea of the study. FD took all iris color photographs. JR participated in the sequence alignment. RBJ participated in its design and coordination.

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