Jones Matse
CS-488
Survey Paper: Concepts and ideas in the field of Iris Pattern Recognition

1 Introduction

In today's technological and data intensive world there is a need to ensure people have access only to the information they are authorized to have. The current forms of authentication such as passwords and ID cards aren't entirely reliable. However biometrics offers a solution to the increasing threat of unauthorized access to systems and data. The advantages of biometric data are that it is fairly difficult to duplicate or steal. Biometrics use physiological and behavioral characteristics to authenticate a person's identity.

Iris's have a large amount of detail due to the trabecular meshwork connective tissue, corona, rings, furrows and freckles. Due to the nature of the iris it is seen as an ideal physical biometric for automated identification. It is protected from external influences by the cornea and aqueous humor, surgical modifications are improbable and the iris's natural reaction to light can overcome certain types of artifice. However, initially, the issues surrounding the viability of using the iris for biometric identification were whether it had sufficient degrees-of-freedom. Degrees-of-freedom refers to the number of independent features that allow the iris to be distinguished as unique. Another issue was whether it would be possible to develop an algorithm to extract enough detailed information from live video images, generate a compact code for the iris and come to a decision of identification with high statistical confidence in a reasonable amount of time [3]. Since then there have been a number of solutions developed to overcome these issues. On the other hand, more issues have been identified to counter the effectiveness of automated iris recognition.

For the scope of this paper I will be focusing on iris recognition and the different issues that have been brought to light as well as potential improvements in various areas over the years.

- The Procedure of Iris recognition
- The Enrollment Process
- Image Acquisition
- Improvements

2 Iris Recognition Procedure

The procedure for iris recognition can be broken down into 3 very broad steps: Image acquisition, image analysis, and the decision step.

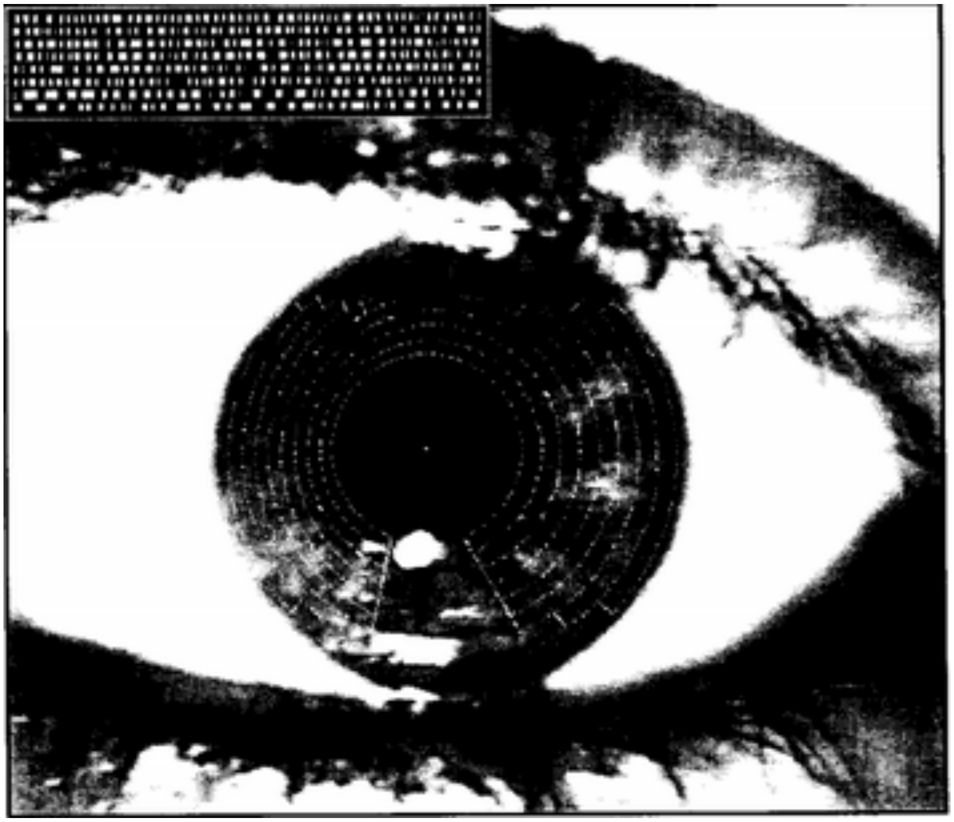
The image acquisition step doesn't only capture an image of the iris therefore the first step of image analysis is to localize the portion of the image which corresponds to the iris [7]. The inner and outer boundaries of the iris have to be determined. However the eyelids obscure the upper and lower limbus of the iris. In addition the eyelid boundary can be difficult to determine because of the presence of eyelashes. Due to the circular geometry of the iris these factors are determined through the first derivatives of image intensities that correspond to the borders of the iris with the mathematical formula:

$$\max_{(r,x_0,y_0)}\left|G_\sigma(r) * \frac{\partial}{\partial r}\oint_{r,x_0,y_0}\frac{I(x,y)}{2\pi r}ds\right|,$$

The quality of the image is then examined. Operations are put in place to examine the boundary between the iris and the white sclera, if the sharpness of the image doesn't show enough of a contrast the operation returns one of three results, there is no eye present, eyelids largely obscure the image or the image is in poor focus or the image's quality is inconclusive [3]. However, multiple frames of the iris image are extracted to determine the presence of an eye.

The textural information of the iris extracted from the images captured and processed by the quality analysis operations [3]. By using 2-D Gabor phasor coefficients images can be more closely analyzed. This family of filters is optimal for providing the maximum possible resolution for information regarding the orientation and special frequency content of a image structure; this gives information of what the images contents are and a 2D location of where. This information is are extremely useful in textual analysis

Sectors of analysis are established on the iris in a "*doubly dimensionless projected polar coordinate system*" [3]. This coordinate system is put in place to maintain reference to the same regions of an iris irrespective of the level of pupillary dilation or constriction and size of the image. Since the pupil in not central to the iris the coordinate system is not concentric. The elastic trabecular meshwork of the iris is modeled by the doubly dimensional coordinate system, which is normalized by the rubber sheet model during pupillary contraction or dilation. So each coordinate is given a point on the iris that can be transformed after pupil dilation or at a different angle of capture for matching [2].



Zones of analysis often leave out the top of the iris where upper eyelid occlusion is frequent and a 45° notch at the bottom where there is a corneal specular reflection from the light source that illuminates the eye from below. This system requires illumination from an angle for people wearing eyeglasses.

The next step involves encoding the information gained through the image analysis into a 256-Byte *Iris Code "* [3]. All irises are mapped into a universal format of constant length to make comparisons and matching of iris codes standardized.

The final step involves having the iris recognition system in place to make a decision in whether the newly obtained iris image matches any of the previously enrolled images in the database. There are four possible outcomes, Acceptance of Authentic (AA), Acceptance of Imposter (IA), Rejection of Authentic (AR), and Rejection of Imposter (IR). The decision-making algorithm focuses on obtaining outcomes AA and IR. The newly captured iris code which has been normalized is compared to one recorded in the database using Hamming distance where Hamming distance is the measure of variations from the two codes using the Boolean XOR operation [3]. If the Hamming distance is larger than a specific range then the image is rejected, if it falls within the range the image is accepted and access will be granted.

The recognition scheme is invariable to planar translation, and rotation due to a head tilt. However, it has been observed that even under a steady illumination the pupillary diameter relative to the iris is constantly changing and this can serve as a test for a living eye [3]. Similarly, monitoring the reaction of a controlled illuminant could provide supporting evidence [7]. On the other hand, some of the folding and unfolding of the iris tissue wont be captured by the rubber-sheet model of the doubly dimensionless polar coordinate system.

3 The Enrollment Process

Daugman and Wildes' methods of image analysis avoid the use of color. The images are rendered in monochrome. This method overlooks the potential of having a first level filter for look-ups in large irises databases [7].
It has been suggested that pupil dilation can affect the accuracy rate of the matching stages of the iris recognition process. It is ideal for the level of dilation at enrollment to be similar at recognition. Daugman's application of the rubber sheet model is described as a good approximation in normalizing the effect of pupillary dilation however it does not model the dilation and constriction of the iris perfectly. It assumes the distortion from pupillary dilation is linear. However there a number of cases where the pupillary dilation shows properties of being non-linear while employing the liner approach during the recognition process. This makes the number of Rejection of Authentic (AR)/ False non-matches higher and this is thought to be partially due to the lack of iris area available for comparison and is mostly evident in scenarios where the difference in pupil dilation is large [5]. Hollingsworth suggested storing the level of dilation as a form of meta-data and taking it into account at the decision stage. Another suggested approach was to store multiple images of varying degrees of dilation at enrollment that is known as quantile enrollment. The enrollment images are chosen at equal intervals of their dilation ratio. Through observations it was found that if the level of dilation is taken into account at the enrollment stage the level of accuracy during recognition is improved. If only one image is to be used as a look-up the image with the median pupil dilation ratio should be used at enrollment [6].

4 Image Acquisition and Analysis

The idea of staying noninvasive to the user of the recognition system raises concerns within the process of image acquisition. Images of high resolution and sharpness are ideal for a valid image recognition process.

The light source used to illuminate the eye during the iris recognition process is an important one. The process of illumination needs to provide the right amount of detail and complexity in the iris's image without annoying the user. Long-wavelength light penetrates the trabecular meshwork revealing only the predominant elements of the iris texture. Initially Daugman used an LED-based point light which is placed below the operator however the issue which occurred is that the position of the light source caused a loss of usable data from the image. Alternatively, Wildes' illumination set up provides a solution at the cost of a fairly more complex set up. Wildes incorporates a diffuse source and polarization. This has the advantage of eliminating the specular reflection from the light source as well as a light source that doesn't disturb the user [7]. On the other hand the near-infrared light can be used from a distance and still produce detailed images of the iris's complex features even in iris with darker pigments [2].

There are already techniques used to obtain focused images of the iris proposed by Daugman and Wildes. Both approaches involve having the user adjust their positions in alignment with the camera to capture focused images. However the ideal system would require the least amount of human cooperation so as to be able to extend its application to a wider selection of fields [7].

In new technologies image focus assessment is the process of positioning the iris in the field of view of the camera to obtain a high quality image of the iris. This can be done by movement of the cameras focus or by repositioning of the user. This is carried out in real time by measuring bands of the 2D Fourier spectrum and moving an active lens or by audio instruction given to the user. The images that pass the minimum focus criteria are sent for analyzing. The accuracy of the localization of the boundaries of the iris has been improved to single-pixel precision [2]. Images with less than 50% of the iris visible are deemed unusable for iris identification. This is most commonly due to the user or subject blinking.

Soft prescription contact lenses have been thought to only slightly affect iris recognition accuracy rate. However this raises the concern that these contact lenses change the properties of the eye over time. Which will affect accuracy of recognition. Contact lenses are known to change positions relative to the position of the iris that causes varied observations during recognition. In addition, there are now cosmetic lenses that have color and textures of their own and this alters the image of the iris during the recognition process. The cosmetic lenses have brought forward the threat of intentional spoofing using similar lens manufacturing technology. Therefore detection of contact lenses needs to be an extension of the current iris recognition process [8].

5 Improvements

Each biometric system has its shortcomings however by combining multiple biometric processes each biometric can compensate for the other and increase recognition accuracy. In addition the use of multi-biometrics limits the chances of successfully spoofing authorization. The most desirable multi-biometric would be comprised of a single sensor to simultaneously acquire multiple modalities for cost and usability efficiency [1]. Fusion of face and iris recognition would be an ideal candidate for this form of multi-biometric if one sensor were to be used. This is one of the emerging improvements in iris recognition that are starting to build popularity.

In the field of biometric recognition there has been a growing interest using continuous video as opposed to still images. This has been seen in facial recognition but not particularly in iris recognition. Using video to capture iris textures can potentially reduce noise from specular reflections or eyelash occlusion. With multiple frames of the iris collected from the video, the images can be averaged and as a result integrate iris image textures [4]. This is an emerging field that has not been thoroughly researched but has potential to improve iris recognition.

6 Conclusion

Iris recognition is a reliable form of identification. Concerns still remain in all the areas of the process. At the same time, solutions to these concerns are gradually being addressed making automated iris recognition a more powerful tool. Their applications as a security tool gradually expand with its potential from the proposed improvements.

7 References

[1] Connaughton, Ryan, Kevin W. Bowyer, and Patrick J. Flynn. "Fusion of Face and Iris Biometrics." In Handbook of Iris Recognition, edited by Mark J. Burge and Kevin W. Bowyer, 219–37. Advances in Computer Vision and Pattern Recognition. Springer London, 2013. http://link.springer.com/chapter/10.1007/978-1-4471-4402-1_12.

[2] Daugman, J. "How Iris Recognition Works." In 2002 International Conference on Image Processing. 2002. Proceedings, 1:I – 33 – I – 36 vol.1, 2002. doi:10.1109/ICIP.2002.1037952.
———. "How Iris Recognition Works." IEEE Trans. Cir. and Sys. for Video Technol. 14, no. 1 (January 2004): 21–30. doi:10.1109/TCSVT.2003.818350.

[3] Daugman, J.G. "High Confidence Visual Recognition of Persons by a Test of Statistical Independence." IEEE Transactions on Pattern Analysis and Machine Intelligence 15, no. 11 (November 1993): 1148–61. doi:10.1109/34.244676.

[4] Hollingsworth, Karen P., Kevin W. Bowyer, and Patrick J. Flynn. "Image Averaging for Improved Iris Recognition." In *Proceedings of the Third International Conference on Advances in Biometrics*, 1112–21. ICB '09. Berlin, Heidelberg: Springer-Verlag, 2009. doi:10.1007/978-3-642-01793-3_112.

[5] Hollingsworth, Karen, Kevin W. Bowyer, and Patrick J. Flynn. "Pupil Dilation Degrades Iris Biometric Performance." Computer Vision and Image Understanding 113, no. 1 (January 2009): 150–57. doi:10.1016/j.cviu.2008.08.001.
———. "Pupil Dilation Degrades Iris Biometric Performance." Comput. Vis. Image Underst. 113, no. 1 (January 2009): 150–57. doi:10.1016/j.cviu.2008.08.001.

[6] Ortiz, Estefan, and Kevin W. Bowyer. "Dilation Aware Multi-Image Enrollment for Iris Biometrics." In Proceedings of the 2011 International Joint Conference on Biometrics, 1–7. IJCB '11. Washington, DC, USA: IEEE Computer Society, 2011 .doi:10.1109/IJCB.2011.6117526.

[7] Wildes, R.P. "Iris Recognition: An Emerging Biometric Technology." Proceedings of the IEEE 85, no. 9 (September 1997): 1348–63. doi:10.1109/5.628669.
———. "Iris Recognition: An Emerging Biometric Technology." Proceedings of the IEEE 85, no. 9 (September 1997): 1348–63. doi:10.1109/5.628669.

[8] Yadav, D., N. Kohli, J.S. Doyle, R. Singh, M. Vatsa, and K.W. Bowyer. "Unraveling the Effect of Textured Contact Lenses on Iris Recognition." IEEE Transactions on Information Forensics and Security 9, no. 5 (May 2014): 851–62. doi:10.1109/TIFS.2014.2313025.
———. "Unraveling the Effect of Textured Contact Lenses on Iris Recognition." IEEE Transactions on Information Forensics and Security 9, no. 5 (May 2014): 851–62. doi:10.1109/TIFS.2014.2313025.