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Iris Recognition: Closer Than We Think?

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Abstract

In this overview we will try to cover the new and emerging Biometric technique of Iris Recognition. The focus will be on image processing and computer vision aspects. Algorithms, systems and their experimental results will be reported. The various templates used will be analyzed in terms of performance and usability. Finally, the overview will cover standardization issues. Throughout the literature only three systems were proposed.

J. Daugman was the pioneer in the field of Iris recognition. In his work the visible texture of a person's iris in a real-time video image is encoded into a compact sequence of multi-scale quadrature 2-D Gabor wavelet coefficients, whose most-significant bits comprise a 256-byte "`iris code." Statistical decision theory generates identification decisions of complete iris codes and calculates decision confidence levels.

R. Wildes created the only competing research. His work was based on a Pyramid Laplacian to perform the 2-D bandbass decomposition in order to represent iris images. A mapping function provided the correct correspondence between them and the Fischer's Discriminant evaluated their similarities. Both of the above works were awarded U.S. Daugman's system was implemented into hardware and commercial products from IriScan are currently available in the market.

W. Boles made the remaining proposal. His approach was based on the calculation of the Zero-crossings of the wavelet transform over concentric circles of the iris. We will describe all three proposals and analyze their similarities and dissimilarities. A detailed description of their systems as well as a detailed analysis of their performance will be reported.

Anatomies and Physiology of the Iris

The human Iris is an internal organ of the eye, protected by the eyelid, cornea and the aqueous humour. It is part of the middle coat of the eye and lies in front of the lens. It is the only internal organ of the body that is normally visible externally. On of its distinctive characteristics is its stability. The iris features remain constant throughout the years. The iris is composed from several layers. Among the visible features of an iris throughout the layers are multiple collagenous fibres, contraction furrows, coronas, crypts colour, serpentine vasculature, freckles rifts and pits. It is seen in cross-section in the anatomical drawing of Figure 1.

Figure 1: Iris

Ophthalmologists originally proposed that the iris of the eye might be used as a kind of optical fingerprint for personal identification [1]. Their proposal was based on clinical results that every iris is unique and it remains unchanged in clinical photographs.

Introduction to Iris Recognition

One of the most dangerous security threats is the impersonation, in which somebody claims to be somebody else. The security services that counter this threat are identification and authentication. The verifier can be identified and authenticated by what he knows (password), by what he owns (passport) or by who he is (Biometrics). The current trend in the research world is headed towards Biometrics since the level of security is highly increased. The most popular biometric features are based on individuals' signatures, retinal, faces, iris, fingerprints, hand and voices.

However, as research evolves the claim that the human Iris is one of the most appropriate features gains way. Ophthalmologists proved to be right and now Iris Recognition is expected prevail as the best way to go for human recognition. It is considered to have the best results along with DNA pattern recognition. Using other Biometrics techniques the probabilities of False Reject (Type I) and False Accept (Type II) error are graphically shown using a graph ranging from 0 to 10 %. Iris Recognition needs a graph ranging from 0-0.09% since reported results show error rates at approximately 0.00076%.

The iris consists of a meshwork of connective tissue, fibres, contraction furrows, rings, and colorations. All these constitute a distinctive fingerprint that can be seen at a distance from the person. The iris meshwork ensures that a statistical test of independence in two different eyes always passes. This test becomes a rapid visual recognition method [2].

In [2] it is mathematically proven that they are sufficient degrees of freedoms in the iris among individuals to impart to it the same singularity as a conventional fingerprint. Efficient algorithms are developed in [2] to extract a detailed iris description reliably from a live video image to generate a compact code for the iris and render a decision about individual identity with high statistical confidence.

As in any other automated recognition technique the iris-recognition system has to compare a newly acquired iris pattern against existing patterns already stored in the system. The iris pattern can be extracted from eye images. The first stage would be an alignment process in order to eliminate variation in scale and rotation. The features that can be used could be based on local orientation, phase or special frequency information.

The properties of the iris that enhance its suitability for use in automatic identification include:

- Protected from the external environment
- Impossibility of surgically modifying without the risk of vision
- Physiological response to light
- Ease of registering its image at some distance

Images of the iris adequate for personal identification with very high confidence can be acquired from distances of up to about 3 feet (1 meter). The striated anterior layer covering the trabecular meshwork creates the predominant texture seen with visible light, (Figure 2), but all of these sources of radial and angular variation taken together constitute a distinctive "fingerprint" that can be imaged from some distance.

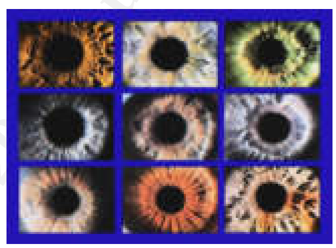


Figure 2: Visible representations of the Iris

When measuring the Iris features and including the other quantifiable parameters as height, width, and location you could end with the massive number of 400 Degrees of Freedom. This number is seven to eight times the number obtained from fingerprints' analysis.

Daugman's work

In Daugman's work [3, 4] the visible texture of a person's iris in a real-time video image is encoded into a compact sequence of multi-scale quadrature 2-D Gabor wavelet coefficients, whose most-significant bits comprise a 256-byte "iris code."

The final outcome of this work was a mathematical proof that there were sufficient degrees-of-freedom, or forms of variation in the iris among individuals, to impart to it the same singularity as a conventional fingerprint. Also uncertain was whether efficient algorithms could be developed to extract a detailed iris description reliably from a live video image, generate a compact code for the iris (of minuscule length compared with image data size), and render a decision about individual identity with high statistical confidence. The final problem was whether the algorithms involved could be executed in real time on a general-purpose microprocessor. During his work all of these questions were resolved and a working system was described.

System Implementation:

Daugman's Iris recognition system consists of an image acquisition rig (standard video camera, lens, framegrabber, LED illuminator and miniature video display for operator positioning interfaced to a standard workstation (Sun 4). The system can operate in three modes including enrolment, verification and authentication. The enrollment and verification modes take less than a second to complete. It has been awarded a US patent. There exists a commercial version of this model through IriScan. In this system further optimization and specific hardware modules were used.

Image Analysis

As we have already mentioned the edge detector operator detects the sharp boundary at the limbus between the iris and the white sclera. However, there are cases that this edge is not present in the picture most frequently due to closed eyelids or even no present of eyes in the image. The system deals with this by continuing grabbing image frames until several frames in sequence confirm the resent of an iris. In the actual system a miniature liquid-crystal TV monitor provides live video feedback helping the users see if their eye is included in the recordings. This procedure also produces some measurements of the reaction of the oscillations in the iris pupil. Something that could be of further use in building even higher security systems since it could overcome special efforts from impostors that could paint an iris in a lens.

Similarly to any other computer vision task of locating a specific feature the iris geometry is exploited. Iris is circular so in order to be located integration and differentiation needs to be applied in order to find the correct location. This is accomplished by maximizing the blurred partial derivative, with respect to increasing radius r, of the normalized contour integral of the image along a circular arc of radius r and the iris center coordinates. The complete operator behaves in effect as a circular edge detector.

After the iris is roughly estimated a second search finds the fainter pupillary boundary, using a finer convolution scale and a smaller search range. The final outcome is the precise location of the outer boundaries of an iris and the pupillary boundary. The search is taking advantage of known physical characteristics of the area like the fact that the sclera is always lighter then the iris so the smooth partial derivatives with increased radius near the limbus is always positive. Some difficulties like the fact that the pupil is not always darker than the iris is resolved by using the absolute value of the partial derivative. This increases the performance of the operator as circular edge detector regardless of these polarities.

In practice all these operations are performed using multi grid search with gradient ascent over the image domain for the centre coordinates and initial radius of each series of contour integrals. The incremental radius and the angular sampling theorem are both decimated in successively finer scales spanning four octaves. It proves to be a very efficient and fast iris locator. The total processing time on a RISC based CPU for accomplishing the iris detection and localization to single pixel-based precision out of a 640 x 480 image only takes 250 msec.

Correspondence

The final codes that will represent the iris have to be extracted from corresponding areas of iris texture. The same regions of the iris need to be tested for similarity. Scaling and the overall iris image can be varied due to pupillary contraction or difference in the camera distance. This is accomplished through the use of a projected polar coordinate system. The stretching of the iris from pupil constriction is modeled through a homogeneous rubber sheet. This sheet has the topology of an annulus anchored along its outer perimeter, with tension controlled by an interior ring of variable diameter. This model assigns a pair of dimensionless real coordinates (radius, angle) to each point of the iris.

After this mapping zones of analysis are defined in this projected doubly dimensionless coordinate system. These zones disregard the top of the iris (usually covered by the eyelid) as well as the area where the light source coming from below causes a corneal reflection. The illumination from an angle even if it causes reflection because it helps avoiding influence from human sunglasses.

Feature Code

In order to construct identifying codes from the analyzed iris textures 2-D Gabor filters are used across multiple scales. More precisely, one of the effective ways for extracting coherent and incoherent textual information from the detailed texture of an iris is the computation of 2-D Gabor phasor coefficients. Daugman introduced these particular filters in 1980. Their mathematical properties include the ability of providing the high-resolution information about the orientation and spatial frequency content of the image structure. Obtaining the required coefficients for these complex functions provide the necessary information needed to represent the iris by its Gabor transform. The final code for the particular Iris (256 bytes) is calculated bit by bit by projecting particular iris regions to the Gabor filters. The number of bytes was selected according to the capacity of the three channel magnetic stripe of the standards credit cards. However, this is the upper bound on the capacity of the iris information.

Using the defined coordinate system the 2-D Gabor filters are designed by adjusting the real parts so as to give them no dc response. This eliminates problems caused by different illumination and contrast gain. The image projections are complex since both real and imaginary parts of these filters are used. Each bit in the iris code corresponds to a coordinate of one of the four vertices of a local unit square in the complex plane. Its value is determined by computing at each scale of analysis the sign of both the real and imaginary part of the quadrature image projections from a local image onto a particular complex 2-D Gabor filter. In other words, a simple 2-D Gabor filter with particular set of size and position parameters performs a phase quantization in the dimensionless coordinate system of the local texture signal.

The time required for computing a complete iris code in the previously mentioned CPU is 100 msec. One of the significant aspects of this code creating procedure is the achievement of using the same length code for all irises, something that was not completely resolved in the fingerprints approach preventing a full-automated system creation.

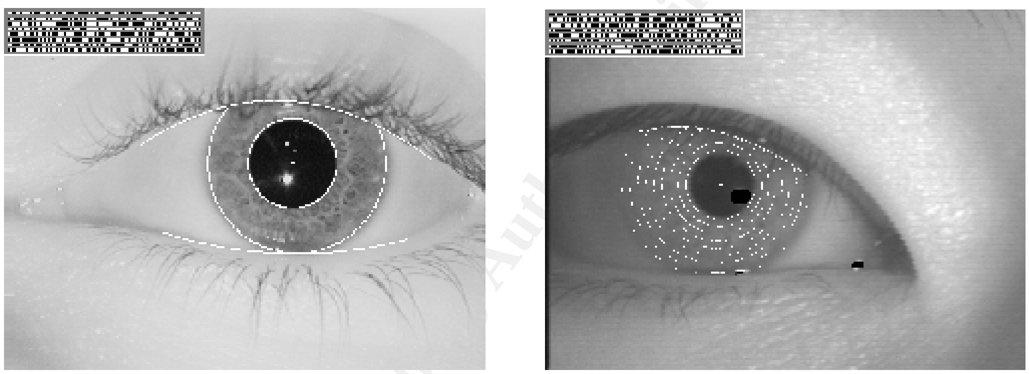


Figure 3: a) Edge Detection ***b) Iris with Segments***

Pattern Recognition:

Samples from stochastic signals with sufficient complexity it is very easy to find ways to check whether two samples show enough agreement to reject the hypothesis they come from independent distributions. In this work demodulating the iris texture and coding the phasor argument converts the problem of pattern recognition to a simple statistical test of independence. In order to reach the recognition result the Hamming Distance of the code of the new iris and all the stored codes is calculated. A simple XOR operation between the corresponding pair of codes provides this Hamming Distance. This is done due to the fact that the iris has approximately 400 degrees of freedom, a number far less than 256 x 8. The reasons for this are the substantial radial correlations within an iris. A furrow usually propagates across the radial distance of the iris and thus its influence is extended in various remote parts of the code. The Fourier Transform of such features can be represented in the various octaves and subsequently in the different scales of analysis. Furthermore, correlation are introduces by the bandpass property of the Gabor Filters.

In order to find this number of degrees of freedom (DOF) the Hamming distance is calculated among a population of unrelated iris codes. The distribution of these distances is finally proved to be corresponding to 173 independent DOF. This includes the subtraction of both the correlation in the iris as well as the correlations included by the filters.

Statistical decision theory generates identification decisions from Exclusive-OR comparisons of complete iris codes at the rate of 4,000 per second, including calculation of decision confidence levels. This extremely fast speed is accomplished through the utilization of the fully vector bitwise comparison form. This form is exploited using the 32-bit architecture of a CPU.

Results.

The original results reported in the research paper were based on a photographic database made available by the Ophthalmology Associates of Connecticut. These images were digitized and combined with other video captured images. The final number of iris images was 592 belonging to 323 individuals. There were approximately three images for each eye. Framegrabber boards (480 x 640 monochrome 8 bits/pixel) digitised the images. The image resolution and the iris size varied to video distance and zoom. The diameter of the iris was always grater than 60 pixels. The images were captured at a distance from 46 mm to 15 cm through a 330 mm positive meniscus lens.

The distributions observed empirically in such comparisons imply a theoretical "cross-over" error rate of one in 131,000 when a decision criterion is adopted that would equalize the False Accept and False Reject error rates. The Hamming Distances for 2064 pairs of "impostors" and 1208 pairs of "authentic" were calculated and their distributions were estimated. These distributions could provide the theoretical probabilities of False Accept of False Reject. The crossover error occurred at a Hamming Distance criterion of 0.321 and the resulting False Probabilities were 1 in 131000 for both cases. In the typical recognition case, given the mean observed degree of iris code agreement, the decision confidence levels correspond formally to a conditional False Accept probability of one in about 10 to the power of 78!!! Needless to say no error occurred in the testing of this database under these parameters and confidence levels. Nearly all-commercial products use Daugman's work and his algorithms are widely accepted. The speed of the recognition made it possible for someone to just place its eye within the focus of a camera and automatically and immediately be recognized or not without any other interaction. In the IrisScan application 200 degrees of freedom were sufficient for perfect recognition rates. Furthermore Iris recognition is less intrusive to humans and thus more accepted to the public as an identification method.

Wildes' work

Wildes in [5, 6] created a similar system. Similarities and differences between the two systems will be discussed in detail in the following section. Having obtained images containing the Iris and the small neighboring area filtering and operating through histogram properties create a voting scheme to describe the iris boundaries. The image is firstly filter with a low pass filter and sub-sampling to reduce noise. A gradient edge detector approximates the boundaries and the eyelids. Then the best fits to the respective parameterized models of boundaries are selected.

To exploit the fact that the iris distinctive information lays both in the whole area as well as in the smaller regions a Laplacian pyramid is used to apply a 2-D transformation. The iris comparison is executed through an area-based image registration technique. A mapping function is searched that brings the data image close the model image. A match value is calculated for the four bands through spatial correlations and the Fisher's Linear Discriminant is responsible for the evaluation of the four values.

System Implementation.

Previous research suggested that in order to obtain good recognition results Iris images had to be sharp and having high resolution. The iris has to be centred and approximately 128 pixels in diameter needed. The remaining concepts that have to be accounted in order to avoid users' discomfort are the levels of illumination (adequate intensity of source but with limited brightness). Furthermore the system needs to avoid reflections that could degrade the recognition performance. Apart from the image's acquisition system the segmentation of the iris has to be achieved.

Wilde proposed an image acquisition system consisting of three subcomponents, each performing one of the required tasks:

Physical capture

In order to obtain high-resolution images of the eye and of good quality he used a low light level white camera (silicon intensified SIT) coupled with a standard frame grabber (Analog DASM-FGM) with resolution 512 x 480 pixels. The diameter of the iris was actually 256 pixels on the sensor array captured at 20cm distance from the eye. This double diameter enabled low pass Gaussian Filters to reduce the high frequency noise.

Illumination

For uniform illumination and users' comfort an array of lights was used (8 50 watt quartz-halogen lamps) directed towards the iris. Uniform illumination was finally achieved by placing a filter (diffusing panel) between the iris and the camera. This panel also helps in distributing the intensity of the light. The lens of the camera is in the center of this diffuser.

Finally, to avoid the influence of reflection a second filter is places in front of the diffuser serving as a circular polariser. This polariser will block the reflection from the cornea (circular object) to reach the camera. On the other hand it does not block the reflection from the light diffusing parts of the eye (iris).

Positioning

The system positions the eye with an automating process guided by a self-positioning operator. The goal is to constrain the three eye degrees of freedom to be imaged by centering it in the sensor array at the focal plane of the lens. The way this is achieved is by the use of square contours and by having the operator align them by adjusting their relative sizes and distances.

Segmentation

This is done through simple filtering and histogram operations. The goal is to isolate the iris from the surrounding areas. Computational efficiency is pursuit through low pass Gaussian filters followed by spatial sub-sampling. This also helps eliminate high frequency noise. Furthermore, it enables a better performance on the boundary detection since the interior details are not necessary at this stage. However, in the pattern recognition stage these areas have to be brought back to their original resolution.
The segmentation is performed using something that reminds a generalized Hough Transform. The iris is located through the subsequent location of its components or inner and outer boundaries (limbic, papillary and the eyelids). This is rather a simple procedure. Edge detectors are used but with different preference directions exploiting the natural characteristics of this sector. Under the logical assumption that the person is at an upright position the visible part of the outer boundary of the iris (limbus) will be at a vertical position. This detects the both the left and right boundary. Changing the preference to horizontal makes the detector look for the eyelid edges. These edges are modelled as parabolas. No direction preference leads to the pupil boundary (inner iris boundary). The natural constraint that increases robustness is the assumption that both the eyelid and the inner boundaries lie within the circle defined by the outer boundaries. Furthermore, the pupil must be above or below the upper and lower eyelid.

Pattern Recognition.

In order to reach the recognition result three parts were formulated in order to choose an iris representation, establish a correspondence between models and test images and evaluating the similarity between them.

Representation

The distinctive characteristics of the human Iris (of connective tissue, fibers, contraction furrows, rings, and colorations) span at a variety of ranges. The overall shape as well as the smaller parts themselves is distinguishable. In order to exploit these characteristics 2-D bandbass decomposition seems a suitable choice. The actual selection was based on octave-wide bands computed at four different resolutions according to the Laplacian Pyramid. Subsambling of the lower frequency bands enables the fast processing and effective storage of the data.

Correspondence

In order to achieve a precise correspondence between the respective structures an area-based image registration technique was used. This function tries to maximize the similarity of pixel values in the input image to the data image. This function also tries to compensate for scale, shift and rotation variation.

Evaluation

Based on the previous correspondence a matching measurement can be calculated through the integration of pixel differences in all the frequency bands available. Spatial correlation was chosen as oppose to standard correlation to eliminate local variation in image intensity. For each band 8 x 8 pixels are used to calculate block correlations and tested versus the median statistic. Since the outcome will be four matching values, one for each frequency band, the

Fischer's Linear Discriminant is used so that the within class variance is minimized and the between classes variance is maximized. The function was trained on five images of ten irises.

Results.

All the concepts discussed (image acquisition, iris localization and pattern matching) were implemented as an automated system able to register as well as verify users. For the registration part five iris images of each individual were adequate. The hardware used was available in the market and the software was written in C.

For testing purposes 50 random individuals were examined. A class of ten was the registration users while the remaining forty would be the "impostors". Five images of the registration users' irises were captured as the training set. For testing the verification part another five images were taken at the same time and another five a month later resulting in 100 total verification tests. The system managed to verify all of them. For testing the rejection part ten images of the forty impostors were taken resulting in 400 total rejection tests. Using the left iris instead of the right twenty additional images were taken from the registration users. Again, the system managed to verify all of them. This system was another example of the possibilities Iris Recognition has as prevailing as the most appropriate mean of recognizing humans.

Boles' work

The most recent work was proposed by Bole in [7, 8] based on calculating the zero crossings of the wavelet transform. In his work apart from the iris location a normalization algorithm brings the iris to have the same diameter and the same number of data points. From the grey levels of the sample images one-dimensional signals are obtained and referred to as the Iris signature. Then a Zero – Crossings representation is calculated based on the Wavelet Transform. These representations are stored as templates and are used for the matching algorithm. In this way the author claims that the noise influence will be eliminated since zero crossings are not affected by noise. Furthermore, 1-D transformations and a fewer number of crossings compared to data points could speed the computations. An interesting aspect of this system is the ability of the wavelet transform to eliminate the effect of glares due to reflection of the light source on the surface of the iris. This was something that was not solved in [4,5,6,7]. However, the recognition results obtained were based on a very small number of images and testing was not as exhaustive and thorough.

System Implementation.

The images used in this system were obtained through scanning from different negatives. The illumination conditions were varied in such a way so as to produce underexposed, overexposed and regular images. Virtual circles were used to collect data (diameter 45 and width 3 pixels). The images size was 128 x 128 pixels. The data was collected using a dyadic wavelet transform on the ordered grey level values sub sampled at a common length of 256 points, producing 8 resolution levels. One of the variations from previous works was testing the various resolutions and choosing the most significant ones (4, 5, and 6 level). These levels contained most of the energy of the iris signature and thus were less affected by noise.

Theoretical Formulation.

Apart from Gaussian maximum filtering Zero Crossings convolved with Laplacian or Gaussian can provide information on sharp variation of image intensity. Under this logic and the fact that distinctive information of the iris lays in different scales Boles used Zero-Crossings multi-scale analysis based on the work already done by Mallat [10]. In [10] the stability of this theory was shown even though in not a completed mathematical framework.

After locating the pupil with the assumption that it composed a circular closed contour the centroid of the pupil is chosen as a point of reference. Using this reference, concentric circles are formed to collect data in circular buffers. From each buffer an "Iris Signature" is generated. This procedure needs an additional normalization process since the diameter of the iris could vary. In order to achieve this, the maximum diameter is chosen as reference and is used to scale the virtual circles diameters to constant size. Normalization also takes place with the data points. Since the same number of points is needed a Normalization value is selected (power of two integer) to help the wavelet transform extract all the information available in the iris signature.

In the wavelet transform a first derivative of a cubic spline function instead of a second derivative of a smoothing function [10]. The maxima and minima of the wavelet transform will correspond to Zero-Crossings. An attempt to minimize the effect of noise is done by choosing only a few resolution levels for the comparison.

Pattern Recognition.

In order to reach the recognition result models of Iris Signatures are made from all the signatures using the same normalization constants for both the users irises as well as the testing irises. Using the number and the location points of the Zero-Crossings a dissimilarity measured is obtained. The iris with the minimum value is chosen as the correct target. The dissimilarity value is the average of the respective dissimilarity values (four) at the various resolution levels. The first two are calculated using all the data points and the final two using only the Zero-Crossings. However, furthermore processes need to compensate for different number of Zero-Crossings.

Results.

The method was tested with a very few images. The testing involved varying lighting and face distances between the model and the testing image of the same iris. The technique was successful in noise free conditions but with different lighting and distances. However, only four tests were performed. When noise was added one failure (approx. 3%) was reported at an SNR = 0.

Comparison on the proposed Methods.

The first two systems were awarded US patents and are subjected to further tests and performance evaluation. They both consist of three similar modules: Image Acquisition, Iris Localization, pattern Matching.

During the evolvement process of the Daugman's system perfect results were reported testing

592 irises. The system was further tested through an IriScan evaluation apart from the experiments during the research evolvement. During the second study, the commercial product was installed in a public space at Sandia National Laboratories, NM. The study involved two phases. During the enrollment stage 122 people produced 199 irises. Then the identification mode was tested. The enrollment users made 878 attempts to be identified and 89 false rejects were reported. However, for 47 for them the system called for a retry that was successful in all but 16 cases. However, no false accepts were reported and the errors were traced to light reflections from eye ware and user difficulties. In the second phase 96 people involved in the first phase tried to be falsely identified in a new database consisting of 403 entries. Again, no False Accepts were recorded. Furthermore, users found no objection in this kind of a system apart from some reports on slight illumination difficulties.

The Wildes' system operated in two modes enrollment and verification analogous to the Daugman system. However, these modes take 10 seconds to complete. No commercial system is available and that is why no optimization image algorithms were persuade at the current time. Furthermore, the system has not been so thoroughly tested. Only one empirical study has been performed. In this study 40 persons created 60 irises consisting of 10 images. No false accepts or false rejects were reported even in the case of irises coming from identical twins.

Boles tried to implement a system extending the current capabilities of the existing two methods. He basically tried to create a system that would not need irises being in the same location within the image of glare free under fixed illuminations. This problem was already solved in Daugman's project by the sequential processing of various frames until the edge detector for the iris localization reported that an iris was present.

Nevertheless, the wavelet transform provided the ability of pattern matching under local distortions hoping to compensate for glares resulting from the reflection of light on the surface of the iris and translation and size variations. He also tried to test the tolerance of his system in different noise levels. Even though the results were good the system was tested with a very small number of images that limits further conclusions. Something that differentiates his work is the analysis of the information in the various resolutions levels. In his attempt to degrease the computational needs he discovered that the intermediate levels contained most of the energy.

Commercial Applications.

One of the biggest promoters of the Iris Recognition technology is IriScan Inc. in Marlton, New Jersey. IriScan holds exclusive patents in the U.S. and 26 countries on the iris recognition concept originated by Drs. Leonard Flom and Aran Safir and the software and process technology invented by Dr. Daugman. Some of the organizations that are currently using their products for access control are US House of Representatives, US Department of Treasury, Bank United (Texas), AK Bank (Turkey), British Telecommunication, Brussels Bank, KPN Telecom (Netherlands), Hewlett Packard, Lake County Sheriff's Office, Olympic memorial Hospital, and surprisingly many others.

Furthermore they have been actively involved with other vendors in attempts to embed this technology in bigger systems. The other vendor is Sensar, Inc. IriScan holds the worldwide patents to the iris scan technology and licenses the technology to Sensar. Currently three products are available to the market:

IriScan's PC Iris

This product is directed towards Computer usage, protection on network information and e-commerce security. SAFLINK Corporation, a wholly owned subsidiary of The National Registry Inc. and IriScan have completed the successful integration and qualification of IriScan's new PC Iris™ authentication system with SAFLINK's Secure Authentication Facility (SAF™) family of enterprise network security products. This allows IriScan to produce complete solution for computer and network security based on the combination of SAFLINK's software applications and IriScan's iris recognition technology and products.

LG's Iris Access 2000

This product is more complex and is directed for usage in the Access Control business instead of a security ID. IriScan has developed, through its partner LG, this active application that automatically captures the iris image from a distance of approximately 12 inches.

An article in the Korean Herald (03/30/2000) announced that LG Electronics is set to enter the local security market by introducing IrisAccess 2000 (developed by IriScan), an access control system based on iris recognition technology. LG designed, manufactured and distributed in North America the IriScan products. The biometrics-based system is expected to replace passwords and identification cards. According to LG Iris Identification will be in higher commercial than retina recognition since it faster, safer, and more cost-effective authentication The access control market in Korea is estimated to reach 50 billion won this year. IrisAccess also has features to increase user convenience, including automatic start, auto focus, and instruction for proper positioning. LG plans to broaden its applications to computer log-on control, e-commerce and financial data protection. The price of IrisAccess 2000 will be set at around 10 million won per unit.

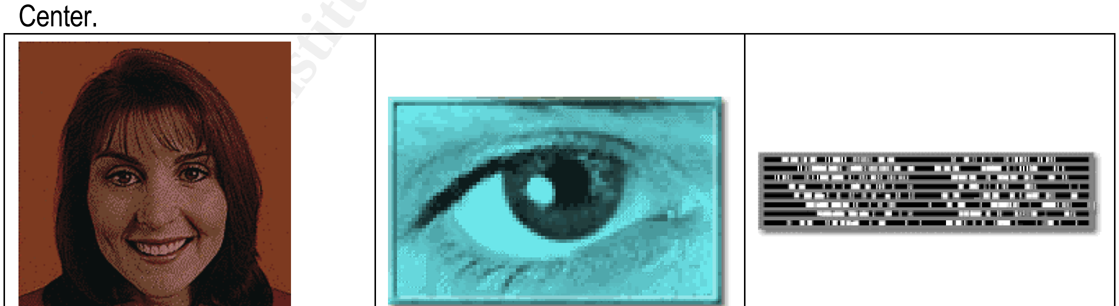
Sensar Secure

Sensar [14] using the IriScan recognition processes (licensed agreement) created Sensar Secure. Sensar has further developed the technology so that the biometric system can automatically locate the user's face and focus the camera from a distance of 3 feet. This is one of the biggest systems. It is the one that is used in ATM and automated financial transaction kiosks. This product was the first that was installed in the US. The iris recognition ATMs (dubbed: Eye TM), were installed at Bank United branches (May 1999) inside Kroger supermarket stores in Houston, Dallas and Fort Worth. A customer has a close-up photo of his eye taken at the bank, and the picture is stored in a computer. When the customer goes up to the ATM to take out money, he presses a button to start an eye scan. The ATM then matches the picture of the iris with the one stored in the bank's database to confirm the customer's identity. Six months later (December 1999) consumer reaction was extremely positive. The customers used words such as: "easy, great, cool, impressive, exciting, fast, convenient, and futuristic." Many of Bank United's EyeTM users cited the new technology as a reason for moving their account to Bank United. They agreed that it is more secure, more convenient, easier, quicker, and more reliable than regular ATMs. They liked the fact that you do not need to use an ATM card (50%). They are more likely to consider Internet banking than non-users and want it to expand. Sensar has traditionally focused on financial industry applications, and they ran a pilot application with NCR at an ATM in England.

Iris recognition was traditionally among the most expensive biometric technologies, costing tens of thousands of dollars. The significant drop in the price of computer hardware and cameras, as well as the partnership between IriScan and LG, has brought the price of the high-end physical security unit into the $4000-$5000 range. The IriScan PC Iris, a proof-of-concept product showing that iris technology can be used be used in the home or office, is priced in the $700-$800 range. IriScan plans to release less expensive, easier-to-use products in the first half of 2000, and hopes to break the $500 price barrier.

Other companies like Oki Electric Industry Co., Ltd. [15], (October, 1999) created similar products. One of their systems would be used as a card-less Internet payment system. Based on Oki's patented chip-to-chip value transfer technology, the new system enhances security by using the iris to confirm a person's identity.

CitX Corporation, producing secure Internet e-Commerce and e-Business solutions, and its healthcare affiliated company IntraMedX Corporation created a strategic marketing relationship with IriScan, Inc. IntraMedX will utilize the iris recognition technology in conjunction with proprietary identity profiling technology and digital certificates to establish the validity of user identities, credentials and the accessibility to different classes of information. IntraMedX expects to establish its iris recognition-based digital certification system as the primary method of identity authentication and the secure access to private or confidential information in the healthcare sector. County and Montgomery County Prison institutions plan to enroll the irises of all inmates into their systems. The Putnam County facility estimates that about 1,000 inmates will be processed annually; Montgomery County estimates 7,000 annually. In addition, IriScan has announced that correctional facilities in Broward County, Florida; Lebanon, Ohio; and Lucasville, Ohio, are also adding the technology to their security protocol. The Sarasota County Sheriff's Office announced that in its first year using an access control iris identification system, it has successfully thwarted two inmate escape attempts at the Sarasota County Detention Center.



a)Picture taken ***b)Eye Localization*** ***c)Code from the Iris***

Figure 4: Functions of the EYE TM in Houston, TX

Figure 5: EYE TM in Houston, TX

Conclusions.

Iris identification was considered one of the most robust ways to identify humans. It provides enough Degrees-of-Freedom for accurate and safe recognition. Iris is considered the most unique, data rich physical structure on the human body. It works even when people were sunglasses or contact lenses.

The properties of the iris that enhance its suitability for use in automatic identification include its natural protection from the external environment, impossibility of surgically modifying without the risk of vision, physiological response to light that is unique, permanent features and ease of registering its image at some distance.

Iris Recognition Systems involve acquiring a picture of a person's iris, digitally encode it, and compare it with one already on file.

Iris identification provides convenience to the human users and is widely accepted.

Dr. John Daugman developed the theoretical research and algorithms.

Theoretically the problem involves edge detection operators (locate the iris), representation and correspondence function (the same parts of the different irises need to be compared, and a matching algorithm. The information contained in the iris structure lies throughout its frequency spectrum. Small and large structures, small and large edges are all distinguishable features (Freckles, Contractile Furrow). In order to exploit this, 2-D decomposition (Gabor Phasor Coefficients, Wavelets) is applied. The frequency components of the various bands are used to extract feature vectors suitable for robust recognition.

The main problems that had to be solved apart from common computer vision drawbacks (scaling, illumination, and rotation) were the reflections of the eye to the light source.
The main disadvantage of Iris Recognition was the designing and manufacturing cost of such a system.

However, Sensar and IriScan products use standard video cameras and real-time image processing at an affordable cost and tremendous speed. The Iris Technology is expanding into the most reliable biometrics feature.

The experiments involved hundreds or thousands of people. However, there exist billions of different irises.

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