BIOMETRIC SECURITY USING IRIS RECOGNITION: A SURVEY

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ABSTRACT-

The Algorithm for Iris recognition was developed by Dr. John Daugman, University Of Cambridge. The iris tests have been tested on over 6 million people with no false results. The recognition principle is the failure of a test of statistical independence on iris phase structure encoded by multi-scale quadrature wavelets. This paper explains the iris recognition algorithm that is being used today in various fields.

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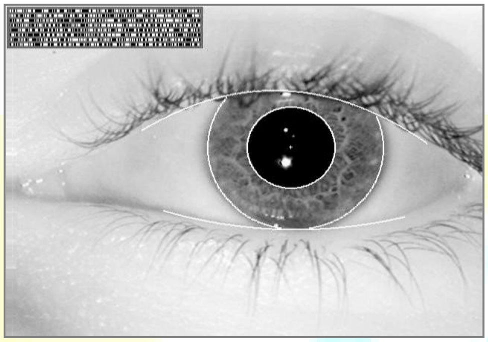
I. Introduction

Reliable automatic recognition of persons has long been an attractive goal. As in all pattern recognition problems, the key issue is the relation between inter class and intra-class variability: objects can be reliably classi_ed only if the variability among different instances of a given class is less than the variability between different classes. Iris recognition technology combines computer vision, pattern recognition, statistical inference, and optics. Its purpose is real-time, high confidence recognition of a person's identity by mathematical analysis of the random patterns that are visible within the iris of an eye from some distance. Because the iris is a protected internal organ whose random texture is stable throughout life, it can serve as a kind of living passport or a living password that one need not remember but can always present. Because the randomness of iris patterns has very high dimensionality, recognition decisions are made with confidence levels high enough to support rapid and reliable exhaustive searches through national-sized databases. The algorithms for iris recognition were developed at Cambridge University by John Daugman. Example of an iris pattern, image. monochromatically at distance of about 35 cm. The outline overlay shows results

Figure 1.1 Example of an iris pattern, image. Monochromatically at distance of about 35 cm.

of the iris and pupil localization & eyelid detection steps→Iris patterns become interesting as an alternative approach to reliable visual recognition of persons when imaging can be done at distances of less than a meter, and especially when there is a need to search very large databases without incurring any false matches despite a huge number of possibilities. Although small (11 mm) and sometimes problematic to image, the iris has the great mathematical advantage that its pattern variability among different persons is enormous. In addition, as an internal (yet externally visible) organ of the eye, the iris is well protected from the environment and stable over time. As a planar object its image is relatively insensitive to angle of illumination, and changes in viewing angle cause only affine transformations; even the non affine pattern distortion caused by pupillary dilation is readily reversible. Finally, the ease of localizing eyes in faces, and the distinctive annular shape of the iris, facilitate reliable and precise isolation of this feature and the creation of a size-invariant representation



The major applications of this technology so far have been:

- substituting for passports,
- aviation security
- controlling access to restricted areas at airports
- computer login
- Access to buildings and homes.

The largest single current deployment of these algorithms is in the United Arab Emirates, where every day about 2 Billion iris comparisons are performed. All travellers arriving at all 17 air, land, and sea ports have their Iris Codes quickly computed and compared against all the Iris Codes in a large database, within about 2 seconds.

II. Locating the Iris

To capture the rich details of iris patterns, an imaging system should resolve a minimum of 70 pixels in iris radius. In the held trials to date, a resolved iris radius of 100 to 140 pixels has been more typical. Monochrome CCD cameras (480 x 640) have been used because NIR illumination in the 700nm 900nm band was required for imaging to be invisible to humans. Some imaging platforms deployed a wide angle camera for coarse localization of eyes in faces, to steer the optics of a narrow-angle pan/tilt camera that acquired higher resolution images of eyes. There exist many alternative methods for finding and tracking facial features such as the eyes, and this well researched topic will not be discussed further here. In these trials, most imaging was done without active pan/tilt camera optics, but instead exploited visual feedback via a mirror or video image to enable cooperating Subjects to position their own eyes within the field of view of a single narrow-angle camera. Focus assessment was performed in real-time(faster than video frame rate) by measuring the total high-frequency power in the 2D Fourier spectrum of each frame, and seeking to maximize this quantity either by moving an active lens or by providing audio feedback to Subjects to adjust their range appropriately. Images passing a minimum focus criterion were then analyzed to find the iris, with precise localization of its boundaries using a coarse-to-fine strategy terminating in single-pixel precision estimates of the center coordinates and radius of both the iris and the pupil. Although the results of the iris search greatly constrain the pupil search, concentricity of these boundaries cannot be assumed. Very often the pupil center is nasal, and inferior, to the iris center. Its radius can range from 0.1 to 0.8 of the iris radius. Thus, all three parameters defining the pupillary circle must be estimated separately from those of the iris. A very effective integrodifferential operator for determining these parameters is:

$$\max_{(r,x0,y0)} \left| G_\sigma(r) * \frac{\partial}{\partial r} \oint_{r,x0,y0} \frac{I(x,y)}{2\pi r} ds \right|$$

Where, I (x; y) is an image such as Fig 1 containing an eye. The operator searches over the image domain (x; y) for the maximum in the blurred partial derivative with respect to increasing radius r, of the normalized contour integral of I (x; y) along a circular arc ds of radius r and center coordinates (x0 ; y0). The symbol * denotes convolution and $G_\sigma(r)$ is a smoothing function such as a Gaussian of scaleσ. The complete operator behaves in effect as a circular edge detector, blurred at a scale set by σ, which searches iteratively for a maximum contour integral derivative with increasing radius at successively finer scales of analysis through the three parameter space of center coordinates and radius (x0 ; y0 ; r) defining a path of contour integration. The operator in (1) serves to find both the pupillary boundary and the outer (limbus) boundary of the iris, although the initial search for the limbus also incorporates evidence of an interior pupil to improve its robustness since the limbic boundary itself usually has extremely soft contrast when long wavelength NIR illumination is used. Once the coarse-to-fine iterative searches for both these boundaries have reached single pixel precision, then a similar approach to detecting curvilinear edges is used to localize both the upper and lower eyelid boundaries. The path of contour integration in (1) is changed from circular to accurate, with spline parameters fitted by standard statistical estimation methods to describe optimally the available evidence for each eyelid boundary. The result of all these localization operations is the isolation of iris tissue from other image regions, as illustrated in Fig by the graphical overlay on the eye.

III. Location of Iris Regardless Of Size, Position and Orientation

Robust representations for pattern recognition must be invariant to changes in the size, position, and orientation of the patterns. In the case of iris recognition, this means we must create a representation that is invariant to the optical size of the iris in the image (which depends upon the distance to the eye, and the camera optical magnification factor); the size of the pupil within the iris (which introduces a non-affine pattern deformation); the location of the iris within the image; and the iris orientation, which depends upon head tilt, torsional eye rotation within its socket (cyclovergence), and camera angles, com pounded with imaging through pan/tilt eye-finding mirrors that introduce additional image rotation factors as a function of eye position, camera position, and mirror angles. Fortunately, invariance to all of these factors can readily be achieved.

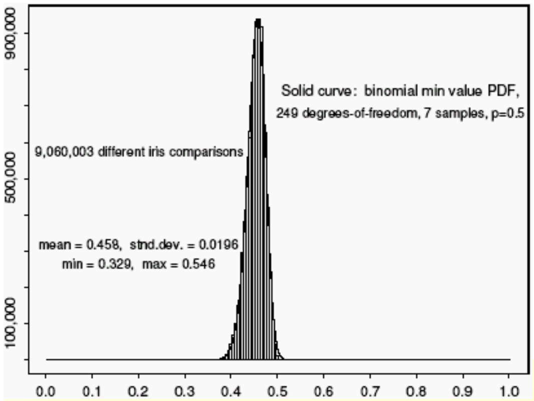


Figure 3.1 Distribution of Hamming distances

For on-axis but possibly rotated iris images, it is natural to use a projected pseudo polar coordinate system. The polar coordinate grid is not necessarily concentric, since in most eyes the pupil is not central in the iris; it is not unusual for its nasal displacement to be as much as 15%. This coordinate system can be described as doubly-dimensionless: the polar variable, angle, is inherently dimensionless, but in this case the radial variable is also dimensionless, because it ranges from the pupillary boundary to the limbus always as a unit interval [0, 1]. The dilation and constriction of the elastic meshwork of the iris then the pupil changes size is intrinsically modeled by this coordinate system as the stretching of a homogeneous rubber sheet, having the topology of an annulus anchored along its outer perimeter, with tension controlled by an (off-centered) interior ring of variable radius. The homogeneous rubber sheet model assigns to each point on the iris, regardless of its size and pupillary dilation, a pair of real coordinates (r; θ) where r is on the unit interval [0, 1] and θ is angle [0, 2π]. The remapping of the iris image I (x, y) from raw Cartesian coordinates (x; y) to the dimensionless non concentric polar coordinate system (r; θ) can be represented as

$$I(x(r,\theta), y(r,\theta)) \rightarrow I(r,\theta)$$

Where, x(r; θ) and y(r; θ) are defined as linear combinations of both the set of pupillary boundary points (xp (θ); yp (θ)) and the set of limbus boundary points along the outer perimeter of the iris (xs (θ); ys (θ)) bordering the sclera, both of which are detected by finding the maximum of the operator (1).

$$x(r;\theta) = (1 - r)xp(\theta) + rxs(\theta)$$

$$y(r;\theta) = (1 - r)yp(\theta) + rys(\theta)$$

Since the radial coordinate ranges from the iris inner boundary to its outer boundary as a unit interval, it inherently corrects for the elastic pattern deformation in the iris when the pupil changes in size. The localization of the iris and the coordinate system described above achieve invariance to the 2D position and size of the iris, and to the dilation of the pupil within the iris. However, it would not be invariant to the orientation of the iris within the image plane. The most efficient way to achieve iris recognition with orientation invariance is not to rotate the image itself using the Euler matrix, but rather to compute the iris phase code in a single canonical orientation and then to compare this very compact representation at many discrete orientations by cyclic scrolling of its angular variable. The statistical consequences of seeking the best match after numerous relative rotations of two iris codes are straightforward. Let f0 (x) be the raw density distribution obtained for the HDs between different irises after comparing them only in a single relative orientation; for example, f0 (x) might be the binomial defined in (4). Then F0 (x), the cumulative of f0 (x) from 0 to x, becomes the probability of getting a false match in such a test when using HD acceptance criterion x:

$$F_0(x) = \int_0^x f_0(x)dx$$

,

$$f_0(x) = \frac{d}{dx}F_0(x)$$

Clearly, then, the probability of not making a false match when using criterion x is 1 - F0 (x) after a single test, and it is [1 - F0 (x)]n after carrying out n such tests independently at n different relative orientations. It follows that the probability of a false match after a "best of n" test of agreement, when using HD criterion x, regardless of the actual form of the raw unrotated distribution f0 (x), is:

$$Fn(x) = 1-[1 - F0 (x)]^n$$

and the expected density fn (x) associated with this cumulative is

$$\begin{aligned} f_n(x) &= \frac{d}{dx}F_n(x) \\ &= n f_0(x)\,[1 - F_0(x)]^{n-1} \end{aligned}$$

IV. ADVANTAGES AND DISADVANTAGES OF IRIS RECOGNITION

Advantages of the Iris for Identification

- Highly protected, internal organ of the eye
- Externally visible; patterns imaged from a distance
- Iris patterns possess a high degree of randomness
    - variability: 244 degrees-of-freedom
    - uniqueness: set by combinatorial complexity
- Changing pupil size confirms natural physiology
- Limited genetic penetrance of iris patterns
- Patterns apparently stable throughout life
- Encoding and decision-making are tractable
    - image analysis and encoding time: 1 second
    - decidability index (d-prime): d' = 7.3 to 11.4
    - search speed: 100,000 Iris Codes per second on 300MHz CPU

V. Genotypic Versus Phenotypic Biometric Features

Genotype refers to a genetic constitution, or a group sharing it, and *phenotype* refers to the actual expression of a feature through the interaction of genotype, development, and environment. *Genetic penetrance* describes the heritability of factors, or the extent to which the features expressed are genetically determined. Those that are (such as blood group or DNA sequence) are called genotypic features, and those that are not (such as iris sequences, as shown above, or to a lesser degree fingerprints) I will call phenotypic features. The latter group may also be called *epigenetic* traits.

Persons who are genetically identical share all their genotypic features, such as gender, blood group, race, and DNA sequence. All biological characteristics of individuals can be placed somewhere along this "genotypic-phenotypic" continuum of genetic determination, with some features (e.g. gender; iris sequence) placed firmly at either endpoint. Other features such as facial appearance reveal both a genetic factor (hence identical twins "look identical") and an epigenetic factor (hence everyone's facial appearance changes over time).

Persons who share 50% of their genes (e.g. a parent and child; ordinary siblings; fraternal twins; and double cousins) show a corresponding partial agreement in their genotypic features such as facial appearance at a given age, but no additional agreement in their epigenetic features.

The importance of these genetic aspects of biometric templates is that they directly influence the two basic error rates: False Match and False non-Match. Nearly one percent of persons have an identical twin, with which they share all genotypic features such as their entire DNA sequence. This creates a minimum False Match rate of 1% (across a population) which we may call the biometrics' genotypic error rate. Similarly, the tendency for some biometric features (such as facial appearance) to change over time creates a minimum rate of False Rejections, which we may call the biometrics' phenotypic error rate. To maximize individuality, distinctiveness, and randomness, a biometric feature should be entirely epigenetic. To maximize stability over the life span, a biometric feature should not change with phenotypic development.

VI. Comparisons between Genetically Identical Iris Patterns

Although the striking visual similarity of identical twins reveals the genetic penetrance of facial appearance, a comparison of genetically identical irises reveals just the opposite for iris patterns: the iris sequence is an epigenetic phenotypic feature, not a genotypic feature. A convenient source of genetically identical irises is the right and left pair from any given person. Such pairs have the same genetic relationship as the four irises of two identical twins, or indeed in the probable future, the 2N irises of N human clones. Eye color of course has high genetic penetrance, as does the overall statistical quality of the iris texture, but the textural details are uncorrelated and independent even in genetically identical pairs. This is shown in the Figure above, comparing 648 right/left iris pairs from 324 persons.

The mean Hamming Distance between genetically identical irises is 0.497 with standard deviation 0.031, which is statistically indistinguishable from comparisons between 9.1 million pairings of genetically unrelated irises This shows that the detailed phase structure extracted from irises by the phasor demodulation process is purely epigenetic, so performance is not limited (as it is for face recognition, DNA, and some other biometrics) by the birth rate of identical twins or by the existence of partial genetic relationships.

Disadvantages of the Iris for Identification

- Small target (1 cm) to acquire from a distance (1 m)
- Moving target ...within another... on yet another
- Located behind a curved, wet, reflecting surface
- Obscured by eyelashes, lenses, reflections
- Partially occluded by eyelids, often drooping
- Deforms non-elastically as pupil changes size
- Illumination should not be visible or bright

VII. IRIDOLOGY

There is a popular belief in systematic changes in the iris patterns, reflecting the state of health of each of the organs in the body, one's mood or personality, and revealing one's future. Practitioners skilled in the art of interpreting these aspects of iris patterns for diagnosing clients' health, personality, and mutual compatibilities, are called iridologists. Like palm-readers, iridologists will offer advice on all of these matters (for a small fee) by inspecting your iris. Of course this is all just hocus-pocus; yet it is popular in California, around the Bay Area, and in parts of Europe such as Roumania

Some limited types of changes in iris appearance can occur and do have a scientific basis: (1) In the first few months of life, a blanket of chromatophore cells in the anterior layer of the iris establishes eye color; until this pigmentation develops, babies typically - even if only temporarily - have blue eyes. (2) Some pharmacological treatments for glaucoma involving prostaglandin analogues are reported to affect melanin, and therefore iris pigmentation, when applied topically to the eye. Such possible changes in iris color are irrelevant for the method of iris recognition described here, as imaging is done with monochrome cameras and using infrared illumination in the 700nm - 900nm band; melanin is almost completely non-absorbant at these wavelengths. (3) Freckles can develop over time in the iris, as elsewhere on the body. Again these are spots of melanin pigmentation, invisible in the infrared illumination used for iris recognition, so they neither help nor hinder in the identification of the iris pattern. (4) Elderly persons' eyes sometimes show a thin white ring surrounding the iris. This is an optical opacity that develops with age in the base of the cornea, where it joins the sclera.

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