Iris Biometrics

University at Buffalo CSE666 Lecture Slides

Resources:
• John Daugman’s webpage: http://www.cl.cam.ac.uk/~jgd1000/
Eye anatomy


J. Daugman “Iris Recognition”, American Scientist, v.89
Eye anatomy

- The structure is formed during first two years of person’s life and does not change (except some rare eye illnesses)
Examples of iris images
Examples of iris images

Figure 3. Concentration of melanin pigment controls the hue of the iris. Blue irises, for example, attain this color because there is only a scant amount of pigment present as dispersed granules, which scatter and reflect shorter wavelengths of light preferentially (a). Although such coloration and the overall anatomy of the iris are genetically controlled, the details one sees in iris tissue arise randomly during gestation. The dark freckles in the iris of this green-eyed subject (b), for instance, are not duplicated in her opposite eye. Although brown irises are sometimes so heavily pigmented that very little detail can be seen within them (c), imaging such subjects using near infrared illumination invariably reveals a great richness of structure (d). The recognition scheme the author helped to pioneer uses such infrared light to obtain images: the computerized system automatically delineates the upper and lower eyelids and the inner and outer boundaries of the iris (blue lines). (Images a, b and c courtesy of Ira S. Tucker; image d courtesy of the author.)
Retina Biometrics?

- Low intensity infrared light reveals the structure of blood vessels on the back of the retina
- More intrusive than iris scan – the camera should be positioned very close to the eye, enrollee training and cooperation required
- Limited to indoor use (low light – larger pupils – better image)
- Earlier deployment (CIA, FBI, NASA)
Algorithm steps

T. Tan et al.”Iris recognition Fundamentals and State-Of-the Art”
Iris localization

Daugman:
search for values \((r, x_0, y_0)\) which give

\[
\max_{(r, x_0, y_0)} \left| G_\sigma(r) \frac{\partial}{\partial r} \int r, x_0, y_0 \frac{I(x, y)}{2\pi r} ds \right|, \quad \text{where} \quad G_\sigma(r) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{r^2}{\sigma^2}}
\]

Explanation:

\[
\int r, x_0, y_0 \frac{I(x, y)}{2\pi r} ds
\]

average grey-scale intensity on the circumference of a circle of radius \(r\) and center \((x_0, y_0)\)
Iris localization

\[
\frac{\partial}{\partial r} \int_{r,x_0,y_0} \frac{I(x, y)}{2\pi r} \, ds
\]

Change in average grey-scale intensity on the circumference of a circle when \( r \) is increasing

- If center \((x_0, y_0)\) is properly located there will be two big changes in intensities – when pupil changes to iris and when iris changes to sclera
- Convolution with \( G_\sigma(r) \) searches for a peak at \( r \) with gaussian of size \( \sigma \)
Example of localization
Zones for calculating features

“Unwrapping” the iris

Fig. 4. Demarcated zones of analysis and illustration of a computed iris code.

Outer boundary (with sclera)

Inner boundary (with pupil)
Gabor Features

Daugman:
use Gabor filters

\[ G_{r_0,\theta_0;\alpha,\beta,\omega}(\rho,\phi) = e^{-i\omega(\theta_0-\phi)} e^{-\frac{(r_0-\rho)^2}{\alpha^2}} e^{-\frac{(\theta_0-\phi)^2}{\beta^2}} \]

Oscillation in
direction of \( \phi \)

Spread in
direction of \( \rho \)

Spread in
direction of \( \phi \)

to extract features

\[ h_{\text{Re}}(r_0,\theta_0;\alpha,\beta,\omega) = ((\text{Re}\int\int_{\rho,\phi} G_{r_0,\theta_0;\alpha,\beta,\omega}(\rho,\phi) I(\rho,\phi) \rho d\rho d\phi) > 0) \ ? 1:0 \]

\[ h_{\text{Im}}(r_0,\theta_0;\alpha,\beta,\omega) = ((\text{Im}\int\int_{\rho,\phi} G_{r_0,\theta_0;\alpha,\beta,\omega}(\rho,\phi) I(\rho,\phi) \rho d\rho d\phi) > 0) \ ? 1:0 \]

Total 256*8 bit features are extracted for each iris
Examples of Gabor Filters
Matching

Hamming Distance between two binary iris codes $A$ and $B$:

$$HD_{raw}(A, B) = \frac{\|\text{code}A \otimes \text{code}B \cap maskA \cap maskB\|}{\|maskA \cap maskB\|}$$

$maskA, maskB$ - specifies which bits are valid

It turns out additional normalization is required to compensate for the number of actually compared bits:

$$HD_{norm}(A, B) = \frac{1}{2} - \left( \frac{1}{2} - HD_{raw}(A, B) \right) \sqrt{\frac{\|maskA \cap maskB\|}{911}}$$
Performance

British Telecom Iris Recognition Trial: Decision Environment

Schiphol Airport Iris Recognition Trial: Decision Environment
Performance

Decision Environment for Iris Recognition: Non-Ideal Imaging

- Same: mean = 0.110, std.dev. = 0.065
- Different: mean = 0.458, std.dev. = 0.0197

$d' = 7.3$
2.3 million comparisons

Decision Environment for Iris Recognition: Ideal Imaging

- Same: mean = 0.019, std.dev. = 0.039
- Different: mean = 0.456, std.dev. = 0.020

$d' = 14.1$
482,600 comparisons
NIST evaluation (NISTIR 7408)
Examples of NIST evaluation images

NIST image 242161: Quality Score = 10/100

NIST image 246215: Quality Score = 5/100

NIST image 246587: Quality Score = 2/100

NIST image 240596: Quality Score = 40/100 (patterned contact lens)
Examples of NIST evaluation images

NIST image 245268: Quality Score = 9/100 (patterned contact lens)

NIST image 243887: Quality Score = 37/100 (patterned contact lens)

NIST image 242245: Quality Score = 13/100

NIST image 241307: Quality Score = 0/100 (interlaced raster shear)
• Bits in iris code seem to be independently randomly generated
• Model the distribution between two irises as a Hamming Distance between two randomly generated binary strings of length $n$
• $n=249$ seems to give a theoretical distribution of HD close to real-life impostor distribution
• 256*8 total –249 random = “not needed”? - spatially close bits might be dependent
Further Research

- Periocular recognition (eye region)
- Long distance iris recognition
- Multispectral image acquisition
- Eye modeling (gaze detection, elliptical iris regions)
- Non-linear deformations
- Alternative feature extraction (e.g. LBP)
- Quality of iris templates (illness, aging)
- Iris indexing
Deployment

- Largest deployment – more than 6,500 passengers entering UAE each day are screened against a database of 420,000 persons previously expelled from country
- Time of each search – 1 second
Deployment

Operation Iraqi Freedom

US Correctional Facilities

http://www.securimetrics.com/solutions/
Deployment

Employee access control at airports

Condominium entrance
Deployment (near future)

Advertising

Law enforcement
Afghan girl
Afghan girl