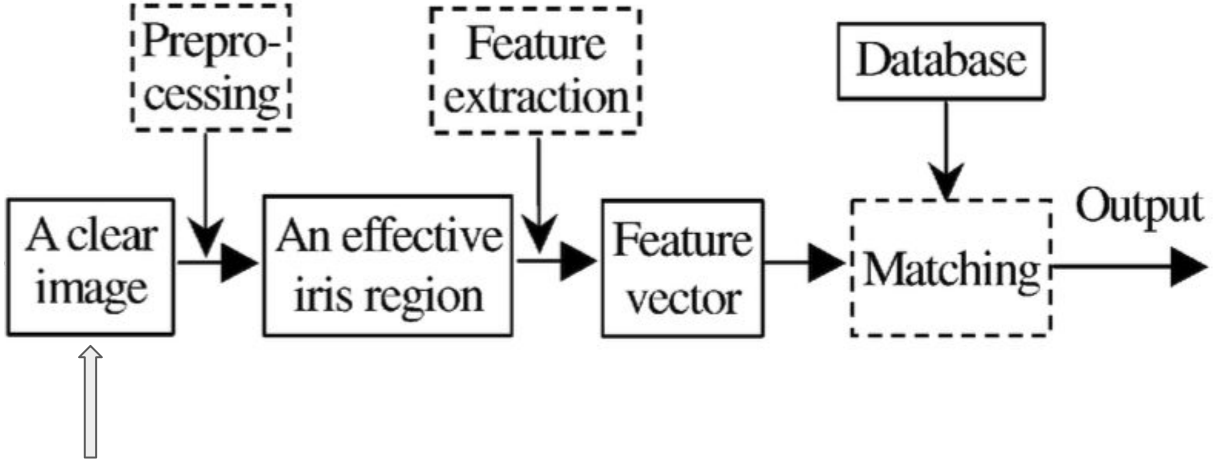
Iris Recognition

Dawei He
2023 Columbia MSCS new grad

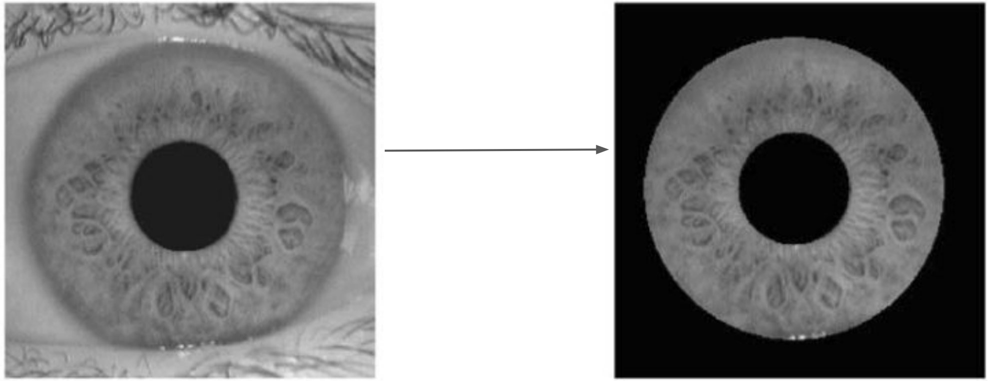
Flowchart of the Iris Recognition System



The CASIA Iris Database includes 2,255 iris image sequences from 213 subjects. Each sequence of the CASIA Iris Database contains around 10 frames acquired in about half a second

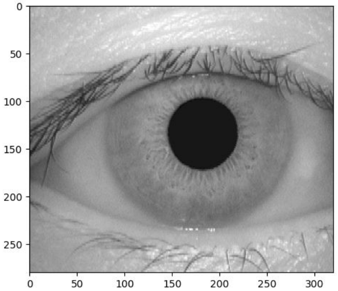
Reference:
Li Ma, Tieniu Tan, Yunhong Wang and Dexin Zhang, "Personal identification based on iris texture analysis," in *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 25, no. 12, pp. 1519-1533, Dec. 2003, doi: 10.1109/TPAMI.2003.1251145.

Image Preprocessing: Iris Localization



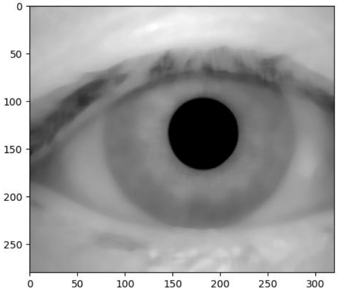
Target: extract effective iris area by removing pupil and sclera (white) area

Image Preprocessing: Iris Localization
- Pupil Localization, detect the inner boundary of iris



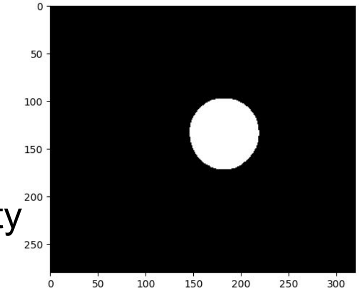
Blur

Gaussian filter



Threshold(mask)

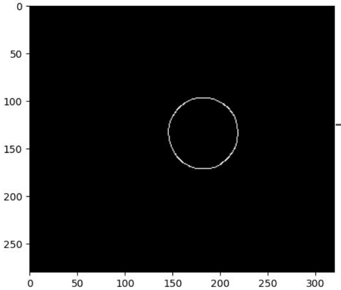
Only retain 0-60 intensity (0-255 grayscale)



- Remove effects of eyelash and eyelid
- Keep the darkest part in the image, which is the pupil

Canny Edge Detection

Look for areas with rapidly changing intensity (keep pixels with gradient magnitudes greater than a threshold)



- Detect the edge of the pupil

Circle Hough Transform

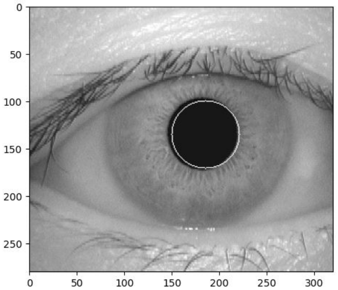
Detect imperfect circles in image

X_p

Y_p

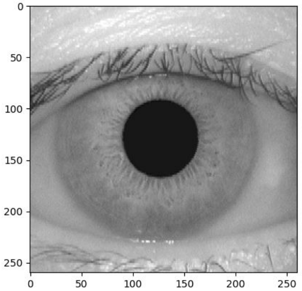
R_p

- Finding coordinate and radius of the pupil



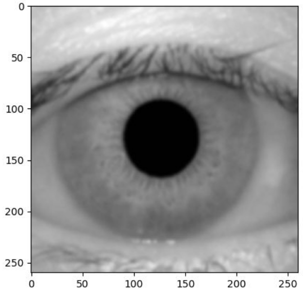
- Localize the pupil

Image Preprocessing: Iris Localization
- Detect the outer boundary between iris and sclera



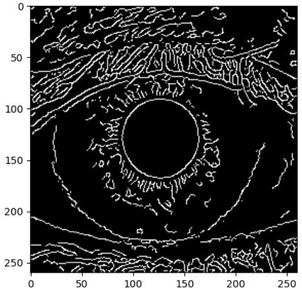
Blur

Gaussian filter



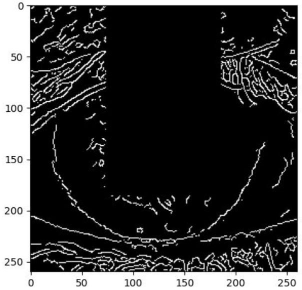
Canny Edge Detection

Look for areas with rapidly changing intensity (keep pixels with gradient magnitudes greater than a threshold)



- Remove effects of eyelash and eyelid
- Detect all edges in the image

Block pupil and part of eyelid area



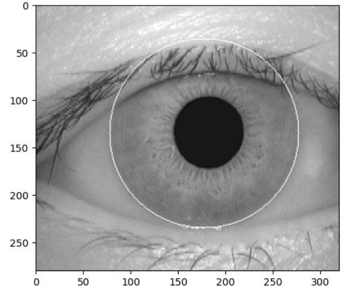
Circle Hough Transform

Detect imperfect circles in image

X_o

Y_o

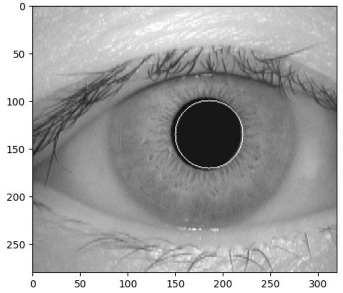
R_o

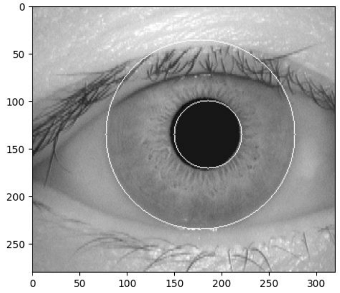


- Remove edges of pupil and eyelid
- Finding coordinate and radius of the outer boundary
- Localize the outer boundary

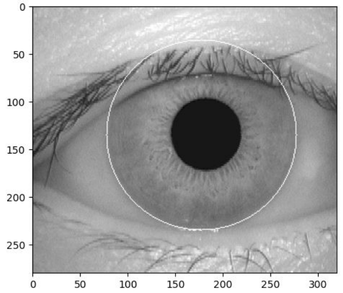
Image Preprocessing: Iris Localization

Inner boundary



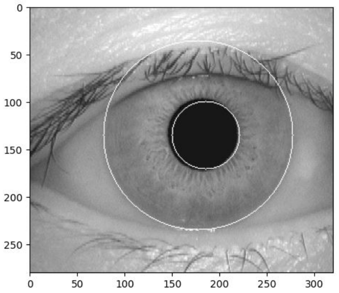


Outer boundary



Iris Normalization

Image Preprocessing: Iris Normalization



Irises from different people may be captured in different size and, even for irises from the same eye, the size may change due to illumination variations and other factors.

We counterclockwise unwrap the iris ring to a rectangular block with a fixed size(64*512) . Such unwrapping can be denoted as:

$$I_n(X,Y) = I_o(x,y)$$

$$x = x_p(\theta) + ((x_i(\theta) - x_p(\theta))\frac{Y}{M}$$

$$y = y_p(\theta) + ((y_i(\theta) - y_p(\theta))\frac{Y}{M}$$

$$\theta = 2\pi X/N,$$

where I_n is a 64*512 normalized image, $(x_p(\theta),y_p(\theta))$ and $(x_i(\theta),y_i(\theta))$ are the coordinates of the inner and outer boundary points in the direction in the original image I_o.

The normalization not only reduces to a certain extent the iris distortion caused by pupil movement but also simplifies subsequent processing (convolution).

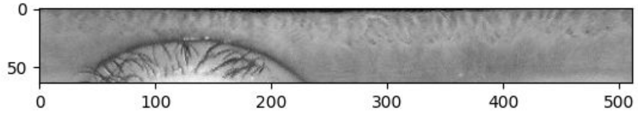
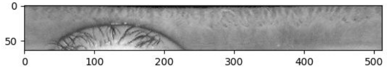
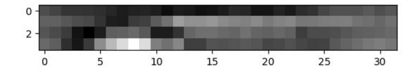


Image Preprocessing: Iris Normalization
- Image Enhancement



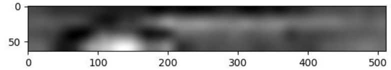
The normalized iris image has low contrast and may have nonuniform brightness caused by the position of light sources.

The mean of each 16*16 small block



Coarse estimate of the background illumination

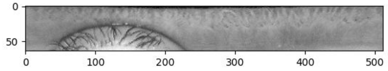
Expanded to the same size as the normalized image



Resize using Bicubic Interpolation to generate a smoother background illumination

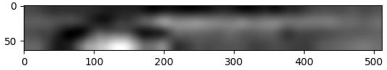
- Approximate intensity variations (background illumination) across whole iris image

Image Preprocessing: Iris Normalization
- Image Enhancement

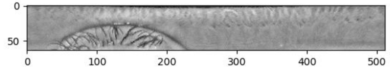


The original normalized iris image

Substruct

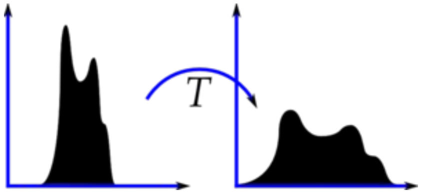


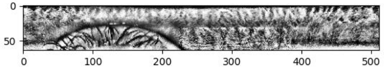
Background illumination



- Uniform background illumination

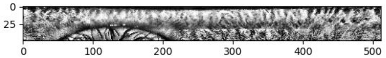
Improves the contrast of tl image by histogram equalization





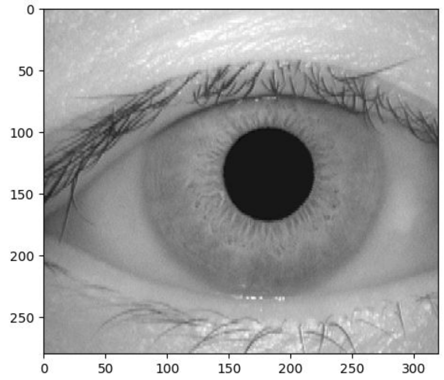
- Clearer Finer texture characteristics of the iris

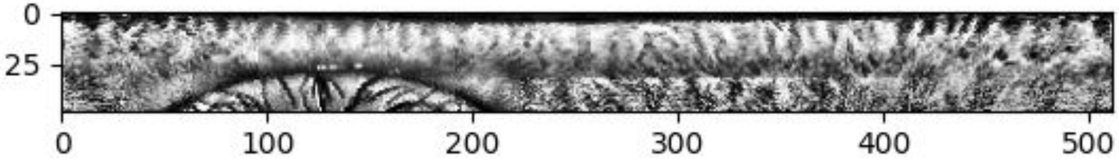
Define upper portion of a normalized iris image (48*512) as Region of Interest(ROI) which closer to the pupil



- Provides the most useful texture information for recognition

Feature Extraction

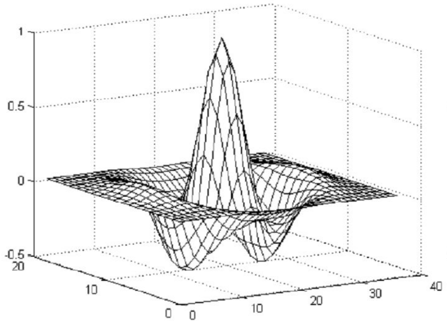




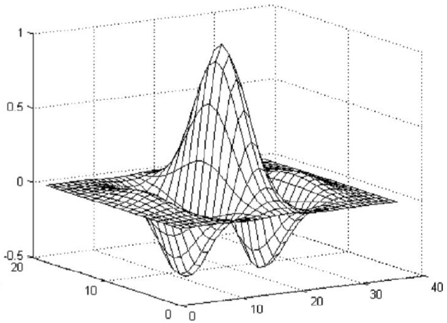
- Local spatial patterns in an iris mainly involve **frequency** and **orientation** information.
- Generally, the iris details spread along the radial direction in the original image corresponding to the vertical direction in the normalized image.
- Frequency information should account for the major differences of irises from different people.
- Orientation information among irises seem to be not significant as frequency.
- In the spatial domain, one can use some specific filters to extract information of an image at a certain orientation, we define new spatial filters based on Gabor filter.

Feature Extraction: Filter

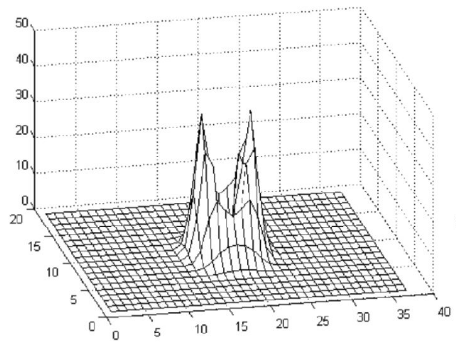
Defined Filter

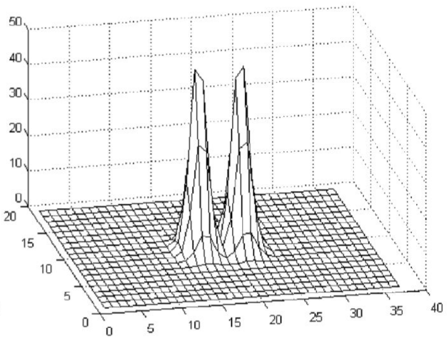


Gabor Filter



Fourier spectra





$$G(x,y,f)=\frac{1}{2\pi\delta_x\delta_y}\exp\left[-\frac{1}{2}\left(\frac{x^2}{\delta_x^2}+\frac{y^2}{\delta_y^2}\right)\right]M_i(x,y,f);$$

$$M_1(x,y,f)=\cos\left[2\pi f\left(\sqrt{x^2+y^2}\right)\right],$$

$$M_2(x,y,f)=\cos[2\pi f(x\cos\theta+y\sin\theta)],$$

where M_1 and M_2 are the modulating function of the defined filter and Gabor filter, respectively

- The former is modulated by a circularly symmetric sinusoidal function, whereas the latter by an oriented sinusoidal function.
- Oriented sinusoidal function is useful for analyzing whether there is any specific frequency content in the image in specific directions
- Circularly symmetric sinusoidal function is useful when features from all orientations need to be considered. When δ_x and δ_y are different, it not only considers information from every orientation but also shows more interest in information in x or y direction
- We use 2 channels (δ_x=3, δ_y=1.5) and (δ_x=4.5, δ_y=1.5)

Feature Extraction: Feature Vector

- Convolution:

$$F_i(x,y) = \iint I(x_1,y_1)G_i(x-x_1,y-y_1)dx_1dy_1; \qquad i=1,2$$

where G_i is the *i* th channel of the filters, $I(x_1,y_1)$ denotes the normalized image, and $F_i(x,y)$ is the filtered image.

- Extract statistical features:

$$m = \frac{1}{n}\sum_w |F_i(x,y)|, \qquad \sigma = \frac{1}{n}\sum_w ||F_i(x,y)| - m| \qquad V = [m_1, \sigma_1, m_2, \sigma_2 \ldots m_{768}, \sigma_{768}]^{\mathrm{T}}.$$

Calculate Mean and standard deviation in each 8*8 small block of the two filtered images. The total number of small blocks is 768[(48*512)/(8*8)*2].

Iris Matching

- Dimensionality Reduction: Improving computational efficiency and classification accuracy

Fisher linear discriminant consider both information of all feature vectors (X_i) and the underlying structure of each class (Y_i). Compared with the most famous method, principal component analysis (LDA), it not only reduces the dimensionality of features but also increases class separability.

The new feature vector f can be denoted as: $f = W^T V$

- Matching unknown iris with database (training data): Nearest center classifier

$$m = \arg \min_{1 \le i \le c} d_n(f, f_i); \qquad n = 1, 2, 3.$$

$$d_1(f, f_i) = \sum_j \left| f^j - f_i^j \right|$$

$$d_2(f, f_i) = \sum_j \left(f^j - f_i^j \right)^2$$

$$d_3(f, f_i) = 1 - \frac{f^T f_i}{\| f \| \| f_i \|},$$

where f and f_i are the feature vector of an unknown sample and the ith class; d1 , d2 , and d3 are L1 distance measure, L2 distance measure and cosine similarity measure, respectively.

- The distances between the feature vector of unknown iris and each class' centroid is calculated.
- Out of all the calculated distances, the class with minimum distance is picked.

Results

Recognition Results Using Different Similarity Measures

Similarity measure	Original feature set	Reduced feature set
L1 distance measure	0.5787037037037037	0.7777777777777778
L2 distance measure	0.49074074074074076	0.8148148148148148
Cosine distance measure	0.42592592592592593	0.8587962962962963