IRIS BIOMETRICS

- Iris is the colored part of the eyes
- Iris is useful for biometric identification because:
  - every individual's iris has a unique pattern
  - it is invariable and permanent, thus, can be tested repeatedly throughout time
  - as an internal organ, it is protected yet physically visible enough for information collection
  - highly accurate verification
IRIS BIOMETRICS: Disadvantages

- Occlusions such as reflections, eyelids, and eyelashes can corrupt iris data.
- Iris image must be taken in highly controlled environment:
  - Facing straight ahead (orthogonal)
  - Little to no movement allowed
- Noisy images can produce inaccurate biometric data.
OUTLINE OF PROPOSED APPROACH

- IMAGE PRE-PROCESSING
  - Acquisition of images from the West Virginia University non-ideal iris image database
  - Reflection removal using morphology

- IRIS SEGMENTATION
  - Outer and inner iris boundaries localization using Daugman's integro-differential operator
  - Occlusions removal using Linear Hough Transform and thresholding

- IRIS REGION NORMALIZATION
  - Using Daugman's Rubber Sheet Model to convert iris image from Cartesian coordinate system to Polar system

- IRIS RECOGNITION
  - Feature Encoding using 1D Log-Gabor filters
  - Feature Matching using the Hamming Distance
IMAGE PRE-PROCESSING

Morphological operation used to remove specular reflections from image:

- The complement of the iris image is taken to make the reflection lighter
- The iris image is then filled with holes to darken the reflections
- The complement of the image is taken again to convert the image back to grayscale
- \[ I = \text{imcomplement} \left( \text{imfill} \left( \text{imcomplement}(I), \text{'holes'} \right) \right) \]

BEFORE REFLECTION REMOVAL

AFTER REFLECTION REMOVAL
IRIS SEGMENTATION: Iris Boundaries Localization

Daugman's integro-differential operator is used to first find the coordinates of the iris boundary:

- First, a possible minimum (rmin) and maximum radius (rmax) value for the iris is set to establish a searching parameter. For the WVU non-ideal database, rmax was set to 50% of the image size and rmin was set to 33% of rmax.

- The operator finds the maximum pixel intensity value change (J) by searching the image within the defined radius parameters with a circular integral centered on the point (x0, y0), with radius r of the radial derivative of the original image blurred with a gaussian kernel G

  - J, in this case corresponds to the iris-sclera (white) boundary since the pixel intensity change is so great between those regions
  - The pupil boundary is then found within the iris-sclera boundary. The pupil boundary corresponds to the second largest value of J.

\[
J(r, x_0, y_0) = G_\sigma(r) \ast (d/dr) \int_{r,x_0,y_0} (I(x,y)/2\pi r) ds,
\]

\[
G_\sigma(r) = (1/(\sigma \sqrt{2\pi})) \exp(-r^2/2\sigma^2).
\]
IRIS SEGMENTATION: RESULT OF IRIS BOUNDARIES LOCALIZATION

Circles whose parameters are estimated using Daugman's integro-differential operator
IRIS SEGMENTATION: Occlusions Removal

- **Eyelid Removal**
  - An edge map of the image is created using canny edge detection.
  - A line is fitted to both eyelids using the Linear Hough Transform.
  - Another line is drawn to bisect the first line at the iris edge closest to the pupil.

- Eyelashes are removed by thresholding since they are usually darker than the eyes. All values less than the threshold value were set to NaN.
NORMALIZATION

The segmented iris region is normalized in order to:

- Obtain a fixed number of features from the iris regardless of its spatial resolution
- Be mapped to a dimensionless fixed coordinated system that is invariant to size changes, i.e. pupil dilation and iris size changes
The Rubber Sheet model maps the coordinates of each Cartesian point from the segmented iris region to polar coordinates \((r, \theta)\) where \(r\) ranges from 0 to 1 and \(\theta\) ranges from 0 to \(2\pi\).
The phase information of the normalized iris is needed to encode only distinctive iris information.

1D Log-Gabor filters are used to convolve the image because:

- They provide phase information.
- They are constructed by modulating sines and cosines waves with a gaussian filter which makes them useful for localizing in space and frequency.
The phase data from the filters are quantised to make the biometric templates and noise masks that are used for matching.

Phase Quantisation Algorithm

\[ H1 = \text{real}(E1) > 0; \quad \% \text{real component} \]

\[ H2 = \text{imag}(E1) > 0; \quad \% \text{imaginary component} \]

\% if amplitude is close to zero then
\% phase data is not useful, so mark off
\% in the noise mask
\[ H3 = \text{abs}(E1) < 0.0001; \]

IRIS TEMPLATE

NOISE MASK: white regions correspond to noise areas previously identified (eyelids, lashes)
The Hamming Distance (HD) is the sum of disagreeing bits of two iris templates divided by the total number of bits.

- HD = 0 if two patterns are from the same Iris...in theory. Since errors can occur during segmentation and normalization, HD should be close to 0 for the same irises but rarely be equal to 0.

Template 1: 00 01 10 11 01
Template 2: 00 01 10 11 01

HD = 0
To account for rotational inconsistencies, when the HD of two templates is calculated, one template is shifted left and right bit-wise.

From the calculated HD values, only the lowest is taken, since this corresponds to the best match between two templates.

Template 1: 00 01 10 11 01
Shift 2 bits right
Template 2: 10 11 01 00 01
TESTING

- West Virginia University non-ideal database:
  - 80 eye images
    - 20 different subjects
    - 4 eye images per subject
  - Non-ideal
    - Eyelash occlusions
    - Rotational inconsistencies

- Intra-Class Comparisons
  - Iris images from same subject are compared to see if the hamming distance is less than a predetermined hamming distance threshold (match)

- Inter-Class Comparisons
  - Iris images from different subjects are compared to see if the hamming distance is more than a predetermined hamming distance threshold (rejection)
EXPERIMENTAL RESULTS

- Used decidability formula to find threshold:
  - \[ D = \text{abs}(\text{mean of intra-class} - \text{mean of inter-class}) \]
    \[ \sqrt{\text{half of the sum of standard deviations of the two classes}} \]

**Used D = 0.40 as threshold**

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<thead>
<tr>
<th></th>
<th>INTRA-CLASS COMPARISONS</th>
<th>INTER-CLASS COMPARISONS</th>
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<tbody>
<tr>
<td>Number of Comparisons</td>
<td>120</td>
<td>3040</td>
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<tr>
<td>False Acceptances</td>
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<td>18</td>
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<tr>
<td>False Rejections</td>
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<td>X</td>
</tr>
</tbody>
</table>

Execution time: 178.475348 seconds
CONCLUSION

Segmentation is the most important part of iris recognition because areas that are wrongly identified as iris regions will corrupt biometric templates resulting in very poor recognition.
SHORTCOMINGS

- Segmentation method could be improved because it yielded inaccurate results for a few images
- Linear Hough Transform was not efficient on some images
REFERENCES