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Advanced Digital Signal Processing Methods – Seminar Report

Iris Recognition for person identification using infrared images

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1. Project motivation

The goal of our project was to design a Matlab script which implements iris recognition algorithm. Algorithms developed by the author for recognizing persons by their iris patterns have now been tested in many field and laboratory trials, producing no false matches in several million comparison tests.

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 classified only if the variability among different instances of a given class is less than the variability between different classes. For example, in face recognition, difficulties arise from the fact that the face is a changeable social organ displaying a variety of expressions, as well as being an active three-dimensional (3-D) object whose image varies with viewing angle, pose, illumination, accoutrements, and age.

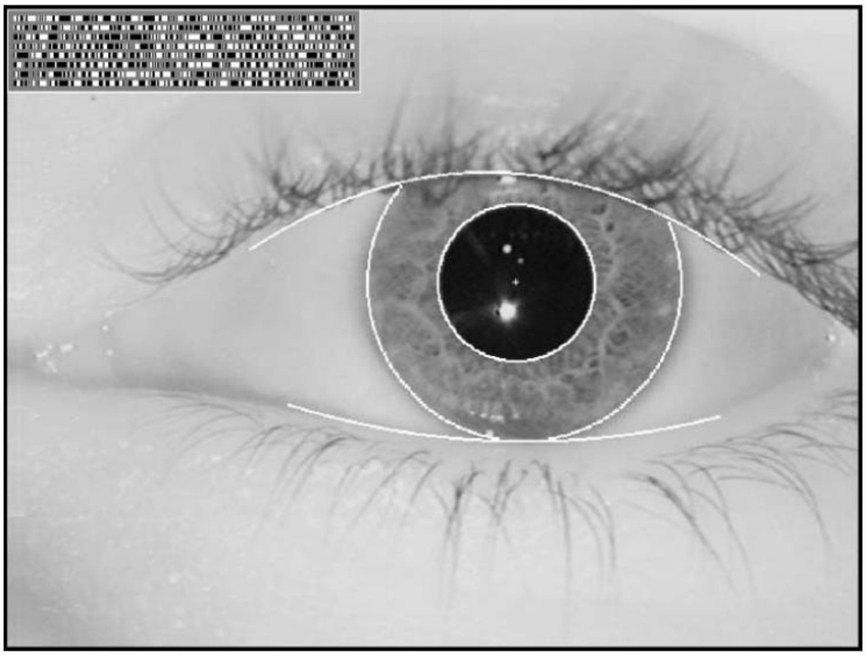


Figure 1.*Example of an iris pattern, imaged monochromatically at a distance of about 35 cm.*

It has been shown that, for "mug shot" images taken at least one year apart, even the best current algorithms can have error rates of 43%–50%. Against this intra-class (same face) variability, inter-class variability is limited because different faces possess the same basic set of features, in the same canonical geometry.

For all of these reasons, 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 nonaffine pattern distortion caused by pupillary dilation is readily reversible.

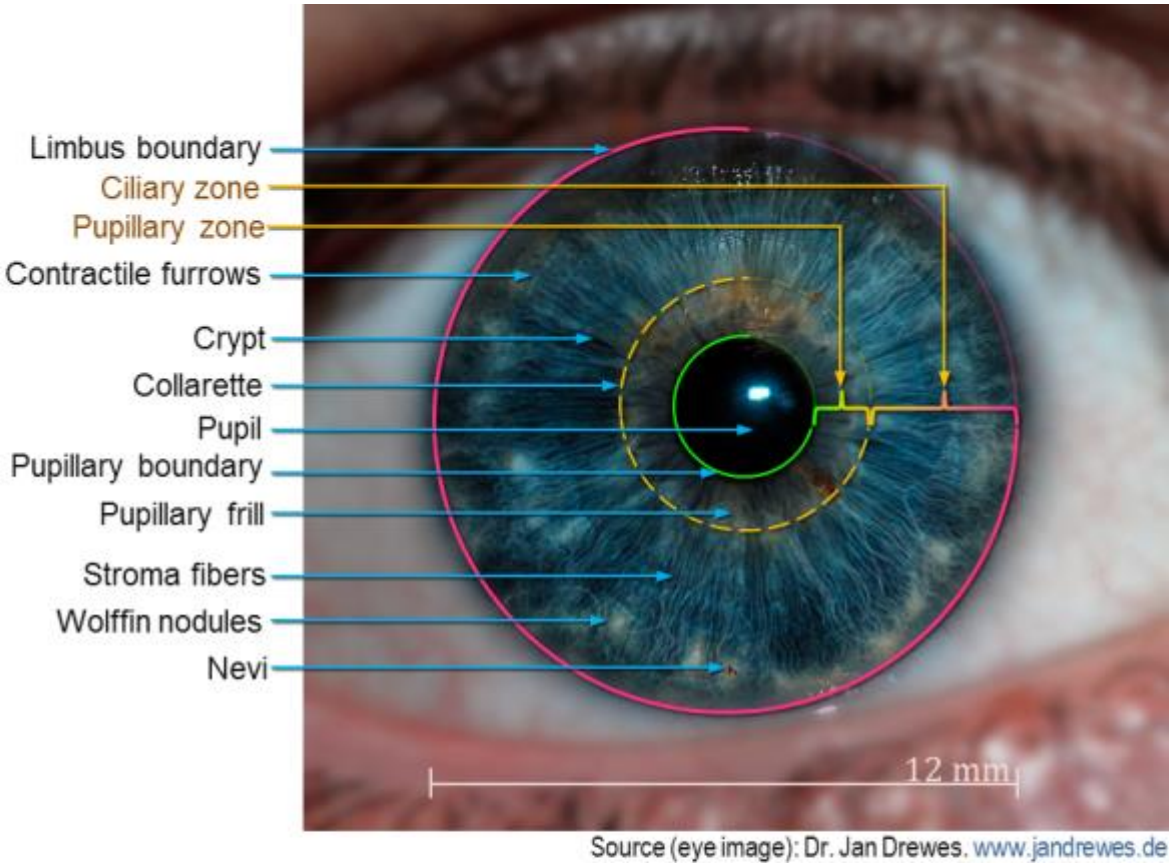


Figure 2. *Complexity and uniqueness of human iris. Fine textures on the iris forms unique biometric patterns which are encoded by iris recognition systems. (Original image processed to emphasize features).*

2. Finding an iris in an image

To capture the rich details of iris patterns, an imaging system should resolve a minimum of 70 pixels in iris radius. In the field trials to date, a resolved iris radius of 80–130 pixels has been more typical. Monochrome CCD cameras (480 640) have been used because NIR illumination in the 700–900-nm band was required for imaging to be unintrusive 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.

Image focus assessment is performed in real time (faster than video frame rate) by measuring spectral power in middle and upper frequency bands of the 2-D Fourier spectrum of each image 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. The video rate execution speed of focus assessment (i.e., within 15 ms) is achieved by using a bandpass 2-D filter kernel requiring only summation and differencing of pixels, and no multiplications, within the 2-D convolution necessary to estimate power in the selected 2-D spectral bands.

Images passing a minimum focus criterion are 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.

Thus, all three parameters defining the pupillary circle must be estimated separately from those of the iris. The operator searches over the image domain for the maximum in the blurred partial derivative with respect to increasing radius, of the normalized contour integral of along a circular arc of radius and center coordinates. The symbol denotes convolution and is a smoothing function such as a Gaussian of scale. The complete operator behaves as a circular edge detector, blurred at a scale set by, searching iteratively for the maximal contour integral derivative at successively finer scales of analysis through the three parameter space of center coordinates and radius defining a path of contour integration. The operator in 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 is changed from circular to arcuate, with spline parameters fitted by statistical estimation methods to model each eyelid boundary. Images with less than 50% of the iris visible between the fitted eyelid splines are deemed inadequate, e.g., in blink. The result of all these localization operations is the isolation of iris tissue from other image regions, as illustrated in Fig. 1 by the graphical overlay on the eye.

3. Feature encoding

Each isolated iris pattern is then demodulated to extract its phase information using quadrature 2-D Gabor wavelets. It amounts to a patch-wise phase quantization of the iris pattern, by identifying in which quadrant of the complex plane each resultant phasor lies when a given area of the iris is projected onto complex-valued 2-D Gabor wavelets.

Only phase information is used for recognizing irises because amplitude information is not very discriminating, and it depends upon extraneous factors such as imaging contrast, illumination, and camera gain. The phase bit settings which code the sequence of projection quadrants as shown in Fig. 3 capture the information of wavelet zero-crossings, as is clear from the sign operator. The extraction of phase has the further advantage that phase angles remain defined regardless of how poor the image contrast may be. Its phase bit stream has statistical properties such as run lengths similar to those of the code for the properly focused eye image. The benefit which arises from the fact that phase bits are set also for a poorly focused image as shown here, even if based only on random CCD thermal noise, is that different poorly focused irises never become confused with each other when their phase codes are compared. By contrast, images of different faces look increasingly alike when poorly resolved and can be confused with each other by appearance-based face recognition algorithms.

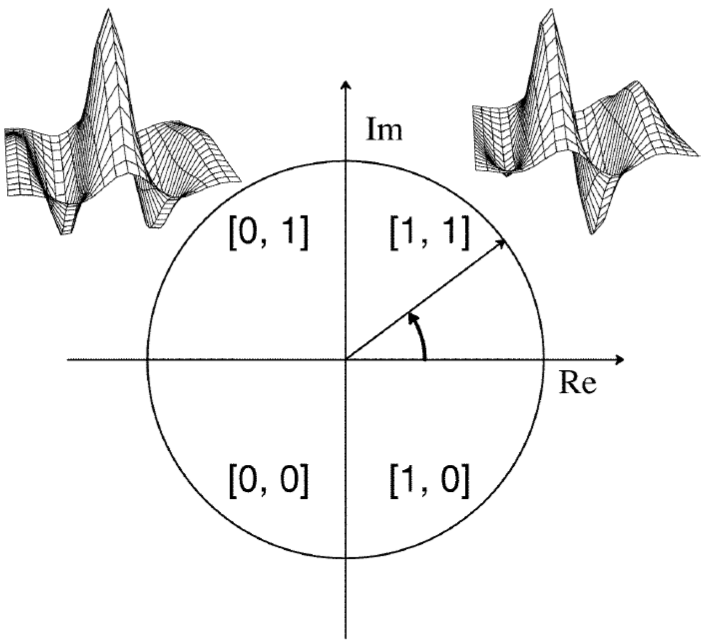


Figure 3. *Phase Quadrant Demodulation Code*

4. Algorithm

a. Iris acquisition

The iris encoding starts with the acquisition of a high quality image of a subject's eye. Almost all iris acquisition systems use near infrared (NIR) illumination in the 720-900 mm wavelengths for iris capture. NIR illumination provides greater visibility of the intricate structure of the iris, which is largely unaffected by pigmentation variations in the iris. There has also been some evidence of the benefits of using visible illumination for iris acquisition, especially for large standoff and unconstrained environments.

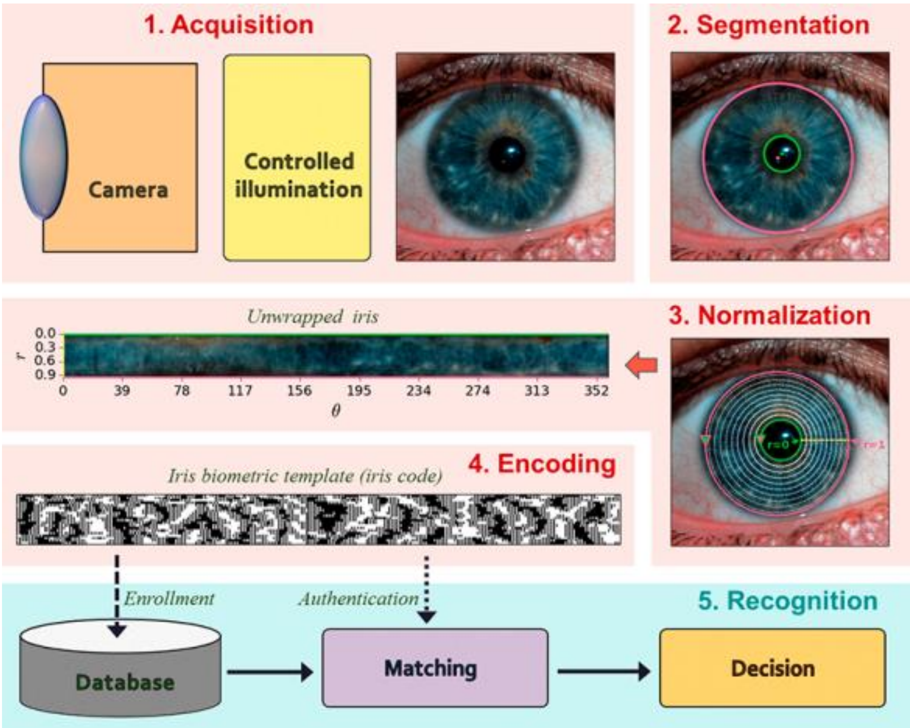


Figure 4. *Overview of iris biometric code generation. The different subsystems of iris recognition include the acquisition module, the segmentation module, the normalization module, the encoding module and the recognition module.*

b. Segmentation and localization

The module following the capture of an acceptable quality iris image is largely known as the segmentation and localization. The goal of this step is to accurately determine the spatial extent of the iris, locate the pupillary and limbic boundaries and identify and mask out regions within the iris that is affected by noise such as specular reflections, superimposed eyelashes, and other occlusions that may affect the quality of the template. A wide gamut of algorithms have been proposed for the segmentation and localization of iris regions, such as Daugman's integro-differential operator, circular Hough transforms along with Canny edge detection, binary thresholding and morphological transforms, bit-planes extraction coupled with binary thresholding, and active contours.

Segmentation and localization is perhaps the most important step in the process of the biometric template generation once a high quality iris image has been acquired. This is because the performance and accuracy of the subsequent stages is critically dependent on the precision and accuracy of the segmentation stage.

c. Unwrapping/Normalization

The spatial extent of the iris region varies greatly amidst image captures due to magnification, eye pose, and pupil dilation/expansion. Furthermore, the inner and outer boundaries of the iris are not concentric, and they deviate considerably from perfect circles. Before the generation of biometric code the segmented iris is geometrically transformed into a scale and translation invariant space in which the radial distance between the iris boundaries along different directions are normalized between the values of 0 (pupil boundary) and 1 (limbic boundary). This unwrapping process, shown schematically in Figure 5, consists of two steps: First, a number of data points are selected along multiple radial curves interspaced between the two iris boundaries. Next, these points, which are in the Cartesian coordinates, are transformed into the doubly dimensionless polar coordinate system of two variables r in [0,1] and θ in [0, 2\Π]. As a result, an iris imaged under varying conditions, when compared in the normalized space, will exhibit characteristic features at the same spatial locations.

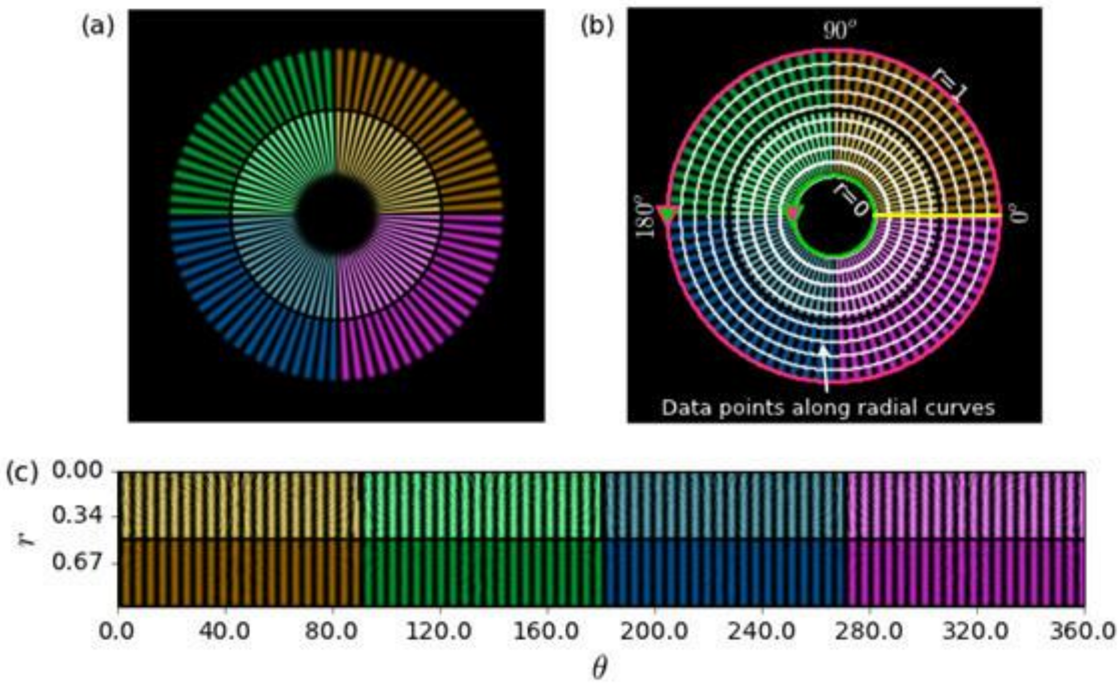


Figure 5. Schematic of the normalization process using a spoke pattern. (a) A spoke pattern; (b) The green and the magenta circles represents the pupil and iris boundaries

d. Encoding – generation of iris code

The encoding process produces a binary feature vector from an ordered sequence of features extracted from the normalized iris image. A large number of iris recognition systems encode the local phase information following multi-resolution filtering by quantizing the phase at each location using two bits. Commonly used multi-resolution filters include 2-D Gabor filter, log-Gabor filters, multi-level Laplacian pyramids, PCA and ICA, etc. Similar to the segmentation module there are numerous algorithms for iris pattern encoding.

e. Recognition – verification/authentication of identity

The spatial extent of the iris region The recognition of iris for subject verification/authentication requires an additional matching step that involves measuring the similarity of a template generated from a newly acquired iris image to one or many templates stored in a database. The most common technique for comparing two iris codes is the normalized Hamming distance (HD) which is a measure of the percentage of locations in which two binary vectors vary. For example, the HD between two orthogonal vectors is 1 whereas the HD between two identical vectors is 0. While an HD of 0 between two iris images from the same eye is highly improbable in practical scenarios pertaining to noise, an HD of 0.33 or less indicates a match.

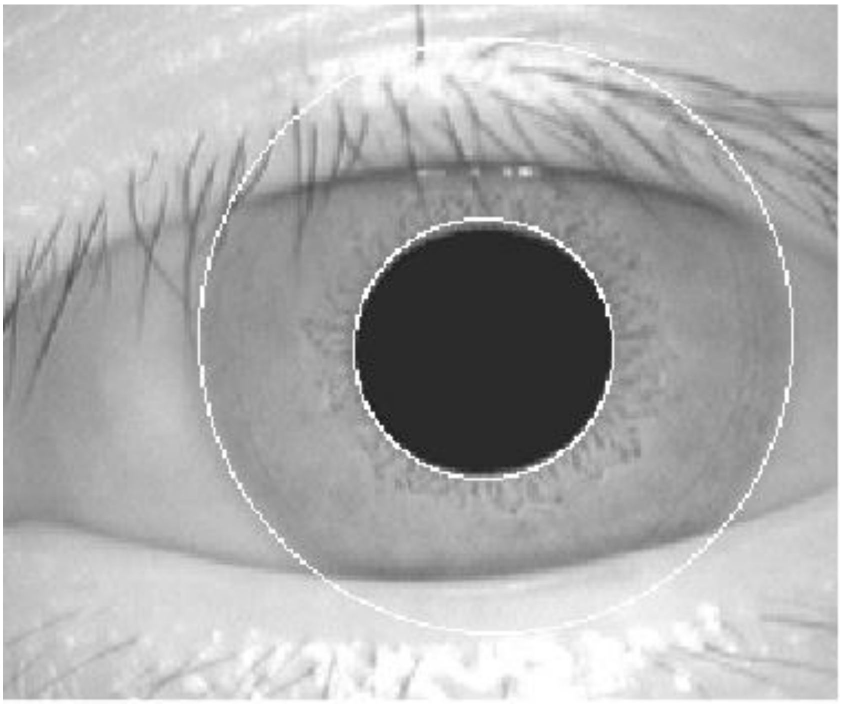


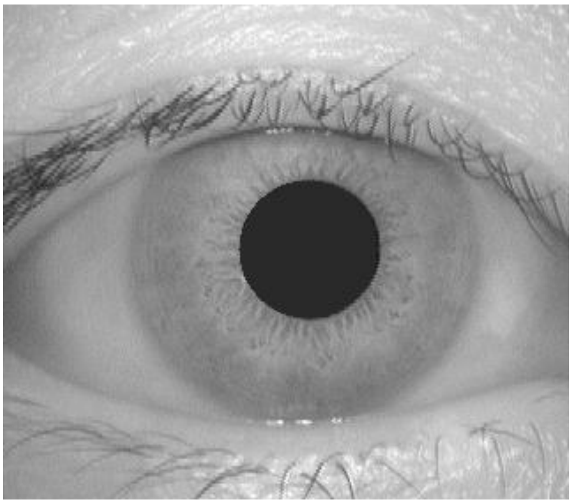
Figure 6. Image of person's eye with region of interest set

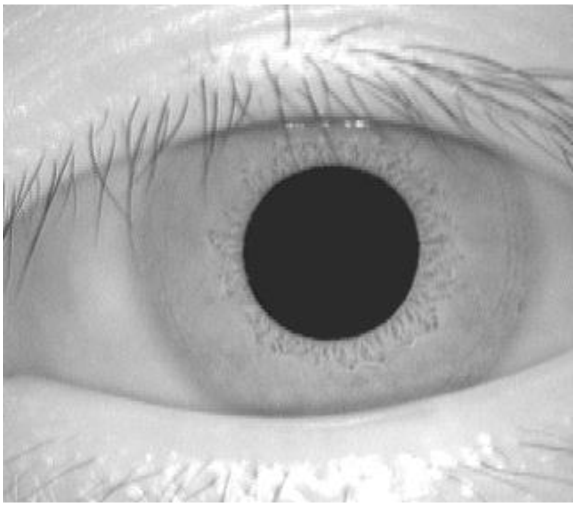
5. Testing Results

In codeIris.m:

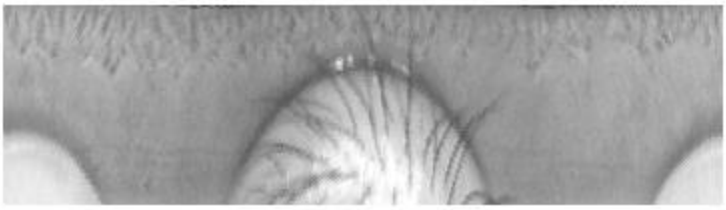
- Input:
    - im -Eye image
    - rmin – The radius of the smaller circle around the pupil
    - rmax – The radius of the bigger circle on the around the iris

We tested the implementation on two pictures:

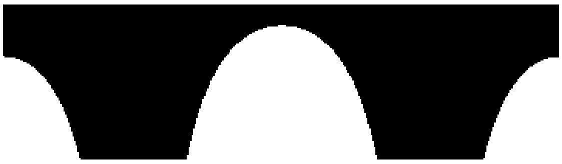


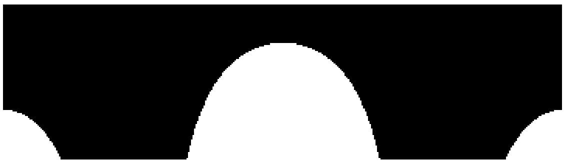


Unwrapped images:

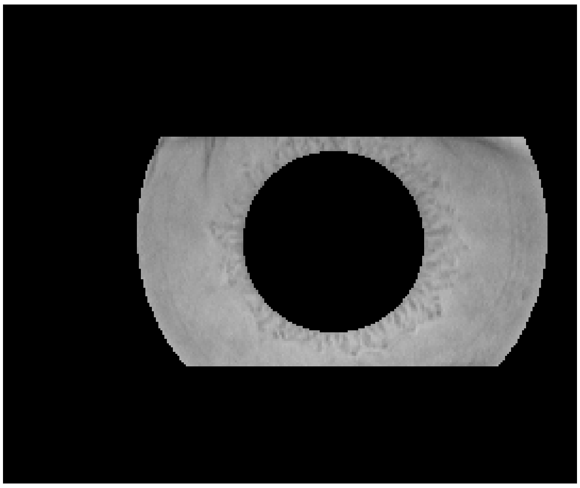


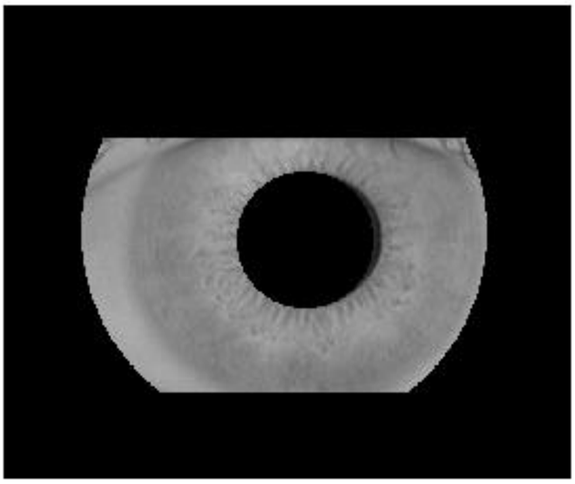
Masks:





Output:





Output 2048 codes

6. Bibliography

[1] John Daugman, “How Iris Recognition Works”, January 2004, IEEE TRANSACTIONS ON CIRCUITS AND SYSTEMS FOR VIDEO TECHNOLOGY, VOL. 14, NO. 1

[2] Primer on iris recognition, 2014, https://indranilsinharoy.com/2014/12/05/dissertation_series/