An Iris Recognition System Using Score-level Fusion of 1-D DCT Transform and Relational Measures

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Overview

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- Advantages of using Iris Biometric
- Motivation
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- Literature Review
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- Strategy Used
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- Experimental Results
- Conclusions
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Introduction

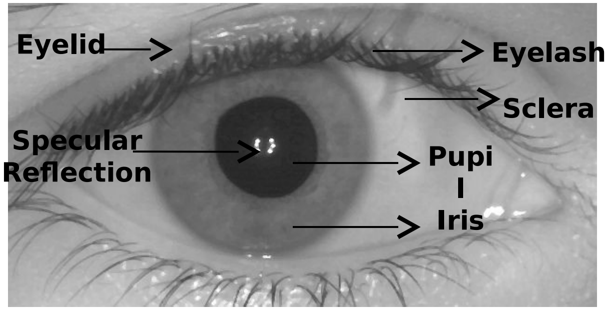


Fig: Iris Anatomy

- Human iris, annular part between sclera and pupil, is selected as biometric trait because of its
  - Uniqueness, stability, non-invasiveness, less circumventive, universal and acceptable characteristics.
- Also, iris has very discriminative texture, so can be used for identification.

Advantages Of Using Iris Biometric

- Universal
- Very high accuracy
- Non-invasive
- Unique
- Invariance of properties(Stability)
- Very high discriminative texture
- Acceptable
- Tamper-resistant
- Verification time is generally less than 5 seconds.

Motivation

- Human iris has unique texture on which biometric recognition techniques can be applied.
- Iris texture varies from person to person, even for twins and left and right eyes of the same individual.
- Iris texture stabilizes by the age of 2 and remains stable thereafter, unless the eye undergoes some physical trauma.
- Pigmentation of iris does not change much after adolescence
- Iris is an overt interval organ, non-invasive, no need to have physical contact with sensing device.

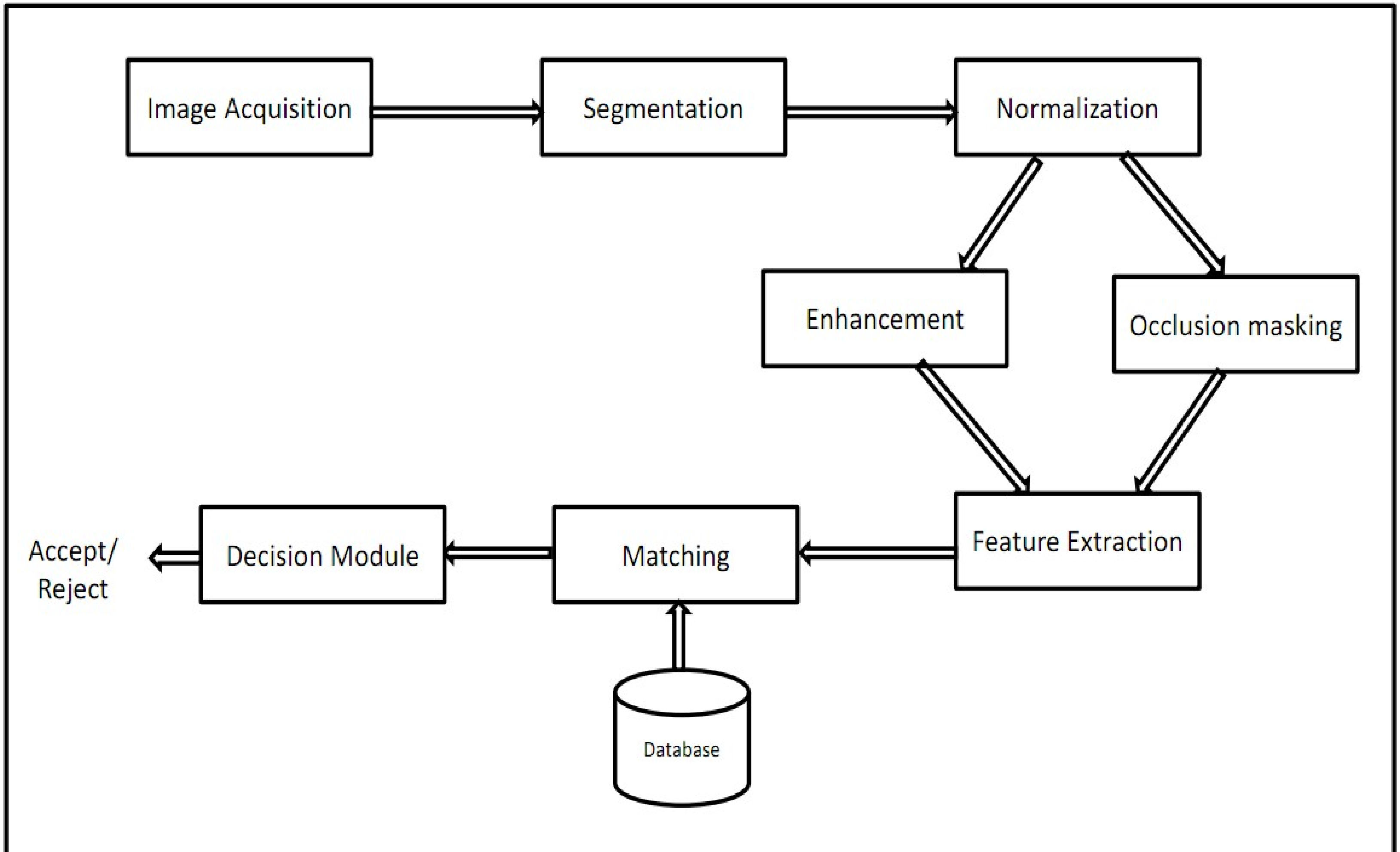
Challenges

- High quality images require proper user-cooperation for image acquisition
- Proper segmentation of Region of Interest (ROI)
- Lighting, motion-blur, off-angle and noise degrade iris image quality
- Physical problems like occlusion due to eyelids, eyelashes and specular reflection
- Rotation and translation effects on image
- Scalability
- Reliability
- Efficiency

Literature Review

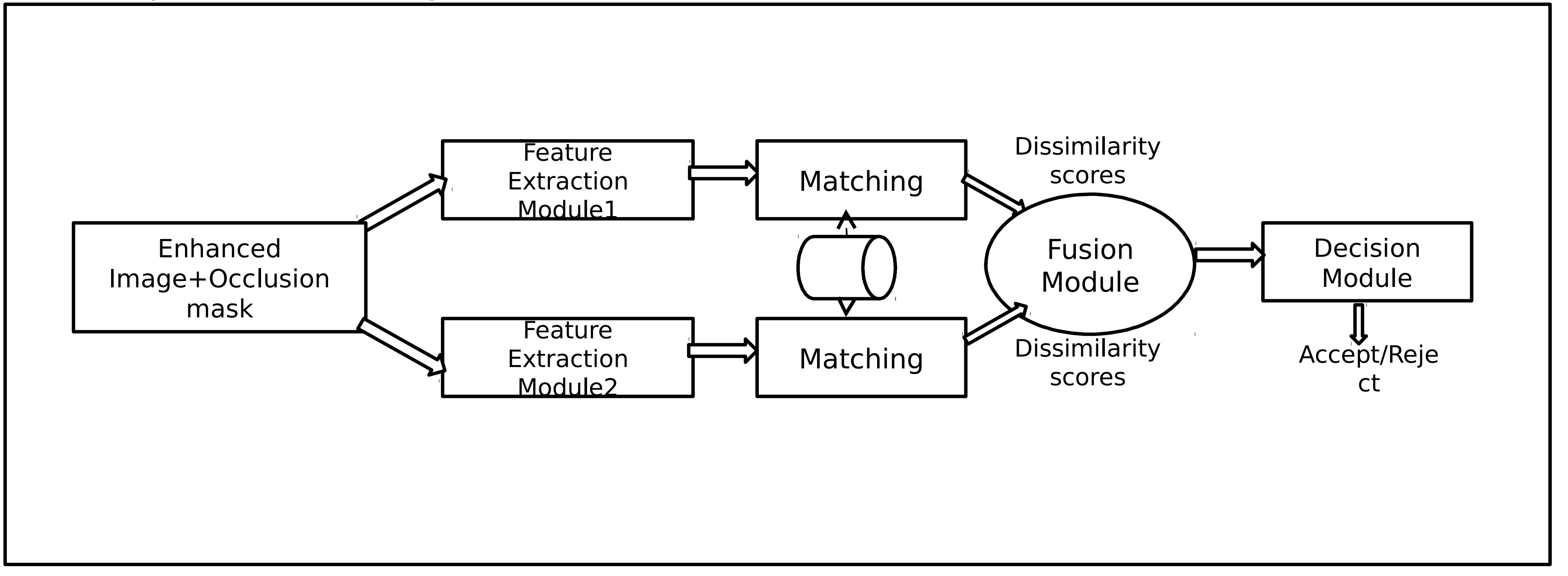
- Flom and Safir [1], first one to propose the concept of iris recognition system
- Daugman used the concept of multi-scale Gabor filters to extract iris features [2].
- In [3], [4], Noisy Iris Recognition Integrated Scheme(N-IRIS) has been proposed for noisy iris images. Two local feature extraction techniques, i.e., Linear Binary Pattern(LBP) and Binary Large Objects(BLOBs) have been combined to design the scheme.
- In [5], a new approach of extracting robust iris features using signals like Discrete Wavelet Transform(DWT) and DCT has been proposed.
- In [6], a new approach of extracting iris features using local frequency variations between adjacent patches of enhanced normalized iris image has been proposed.
- Libor Masek has used 1-D log Gabor filters to extract iris features.

General Iris Recognition System



Strategy Used

- Fusion at matching score level or score-level fusion-The dissimilarity scores generated by the biometric matchers are combined using the technique of weighted averaging to generate a new matching score on which the decision of acceptance or rejection takes place.



Proposed Iris Recognition System Using Score-level Fusion of DCT and RM [7]

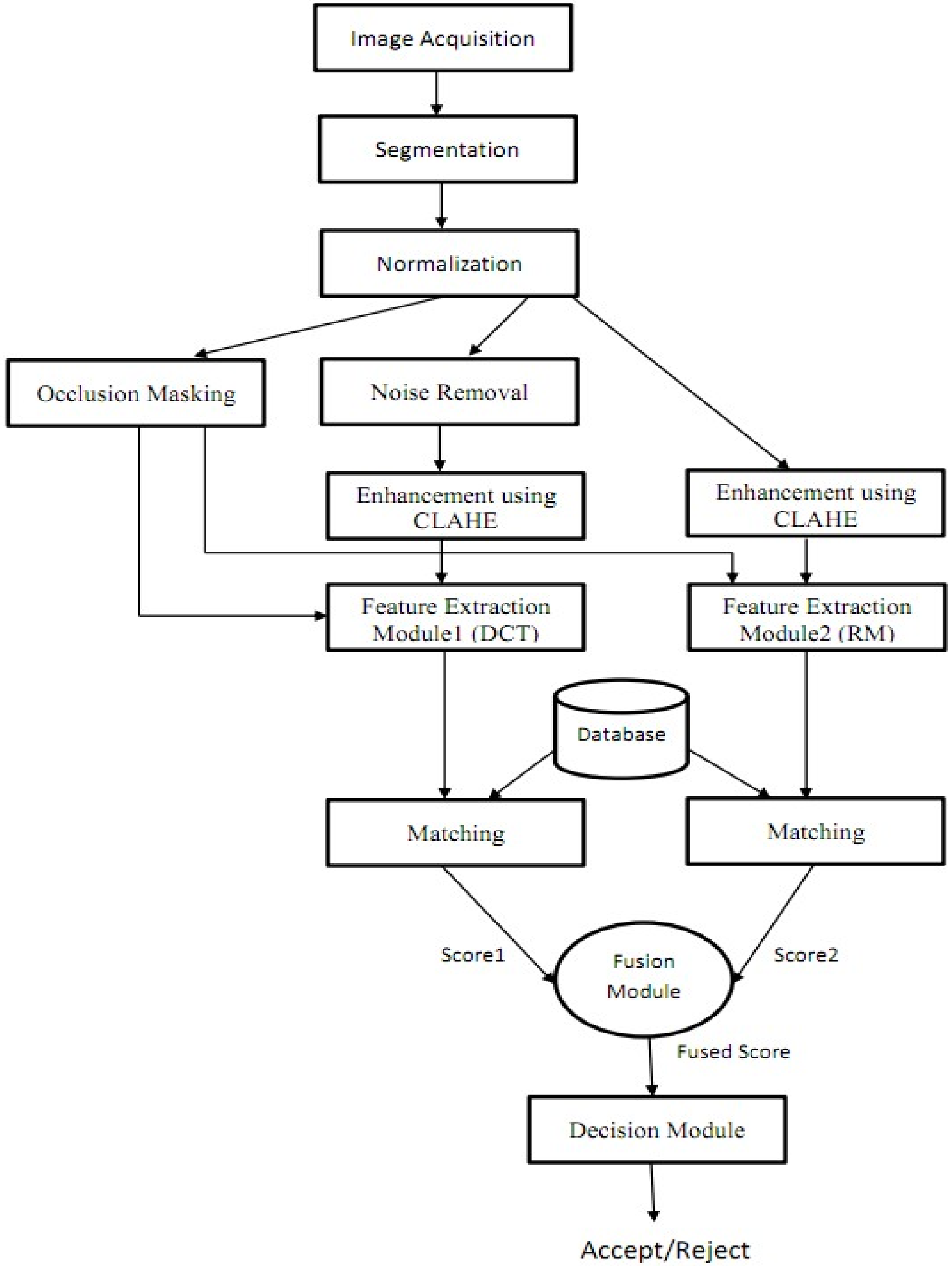
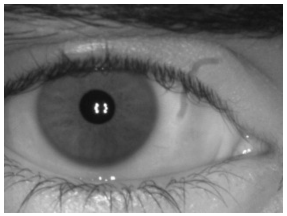


Image Acquisition
Segmentation
Normalization
Occlusion Masking
Noise Removal
Enhancement using CLAHE
Enhancement using CLAHE
Feature Extraction Module1 (DCT)
Feature Extraction Module2 (RM)
Database
Matching
Matching
Score1
Score2
Fusion Module
Fused Score
Decision Module
Accept/Reject

Segmentation , Normalization and Occlusion Mask Detection

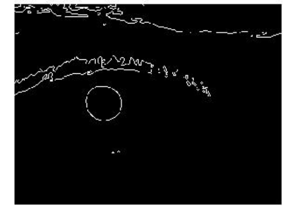
- The inner and outer boundaries of iris are detected in segmentation step [7].
- Inner boundary is detected using Circular Hough Transform.
- Hough Transform is brute-force voting procedure mostly used to detect circular shapes.
- Outer boundary is detected using circular integro-differential operator.
- Integro-differential operator calculates gradient in circular summations of intensity over concentric circles.
- Normalization maps the segmented iris image from cartesian to polar coordinates using Daugman's rubber sheet model. This brings the iris images to same dimension for comparison.
- Occlusion due to eyelashes, eyelids, specular reflections and shadows hides relevant regions of iris which can severely affect the iris recognition giving inaccurate results.
- Normalized image is used for finding the occlusion mask to reduce the working area and making detection efficient.

Segmentation, Normalization and Occlusion Mask Detection-Example

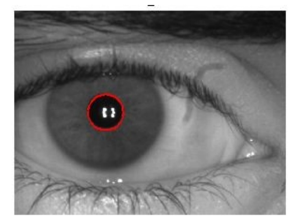


(a) Original Image

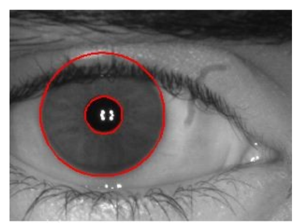
(b) Thresholded and flood-filled Image



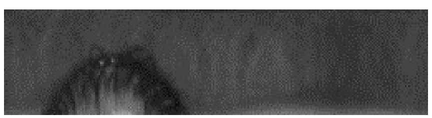
(c) Edge map using Sobel operator



(d) Segmented pupil



(e) Segmented iris



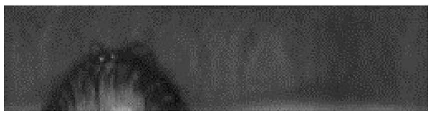
(f) Normalized Image

(g) Occlusion Mask

Denoising and Enhancement

- Noise results in undesired variation in intensity of pixel values.
- Can come in an image through camera or while data transmission or compression of image.
- An average filter of size 4 x 4 is used for smoothening the image.
- It is a sliding-window spatial filter which takes the average of all the pixels in the window and assigns it to the central pixel of the window.
- Removes those pixel values which are quite different from the surrounding.
- Larger window produces blurring effect and also introduces some undesirable pixels in the image data.
- The denoised image may have low contrast and non-uniform illumination.
- Its rich features are made visible using Contrast Limited Adaptive Histogram Equalization (CLAHE) technique.

Denoising and Enhancement-Example



(a) Normalized Image

(b) Denoised Image

(c) Background Illumination Estimate

(d) Uniformly lluminated Image

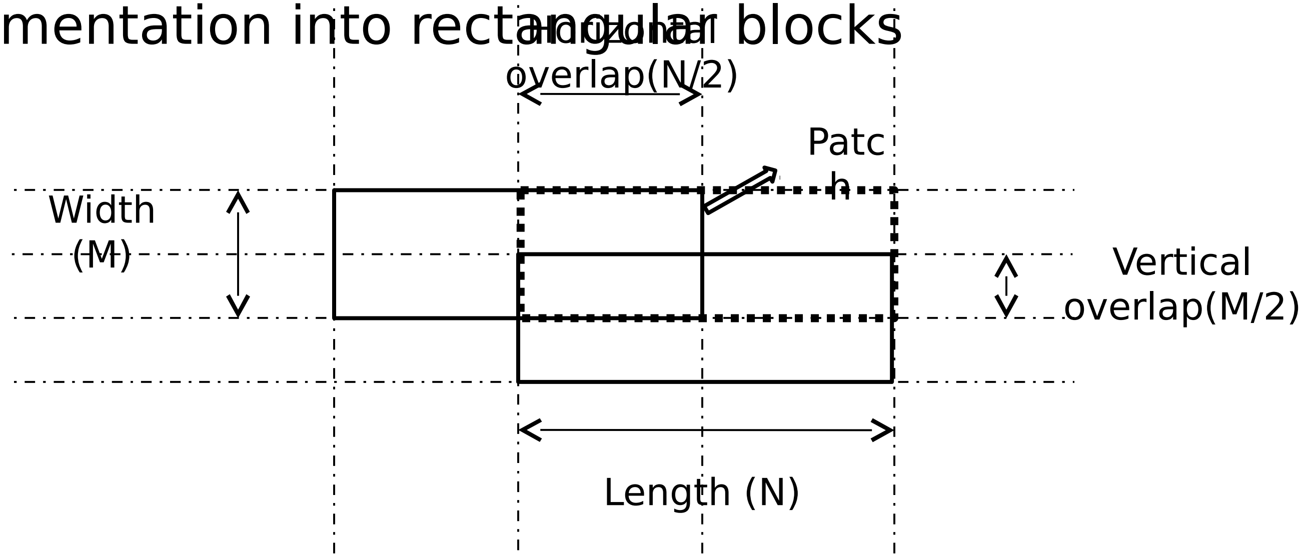
(e) Enhanced Image

Discrete Cosine Transform (DCT)

- DCT is a real-valued transform, so less computationally expensive.
- Robust to illumination
- Mostly used for extracting distinctive features from images
- Compression of images in JPEG and MPEG due to its property of strong energy compaction and also in pattern recognition problems like biometrics.
- Finite sequence in terms of sum of cosine functions which oscillate at different frequencies.
- Transforms a signal representation from spatial form to its frequency form.
- Works well on pixel values lying between -128 to 127 [8], so the image should be first levelled off by subtracting 128 from each pixel entry, before applying DCT on it.

Proposed Feature Extraction Using DCT

- Feature vectors are derived from the zero-crossings of 1-D DCT coefficients.
- DCT works well on pixel values lying between -128 to 127, so 128 is subtracted from each pixel value of the enhanced normalized image.
- Segmentation into rectangular blocks



Overlapping Rectangular Blocks with parameters

- Coding of rectangular blocks
  - The rectangular block is averaged across its width.
  - Formally, a rectangular block of width M and length N, averaged across width gives a 1-D intensity signal R' of size 1 x N which can be represented by

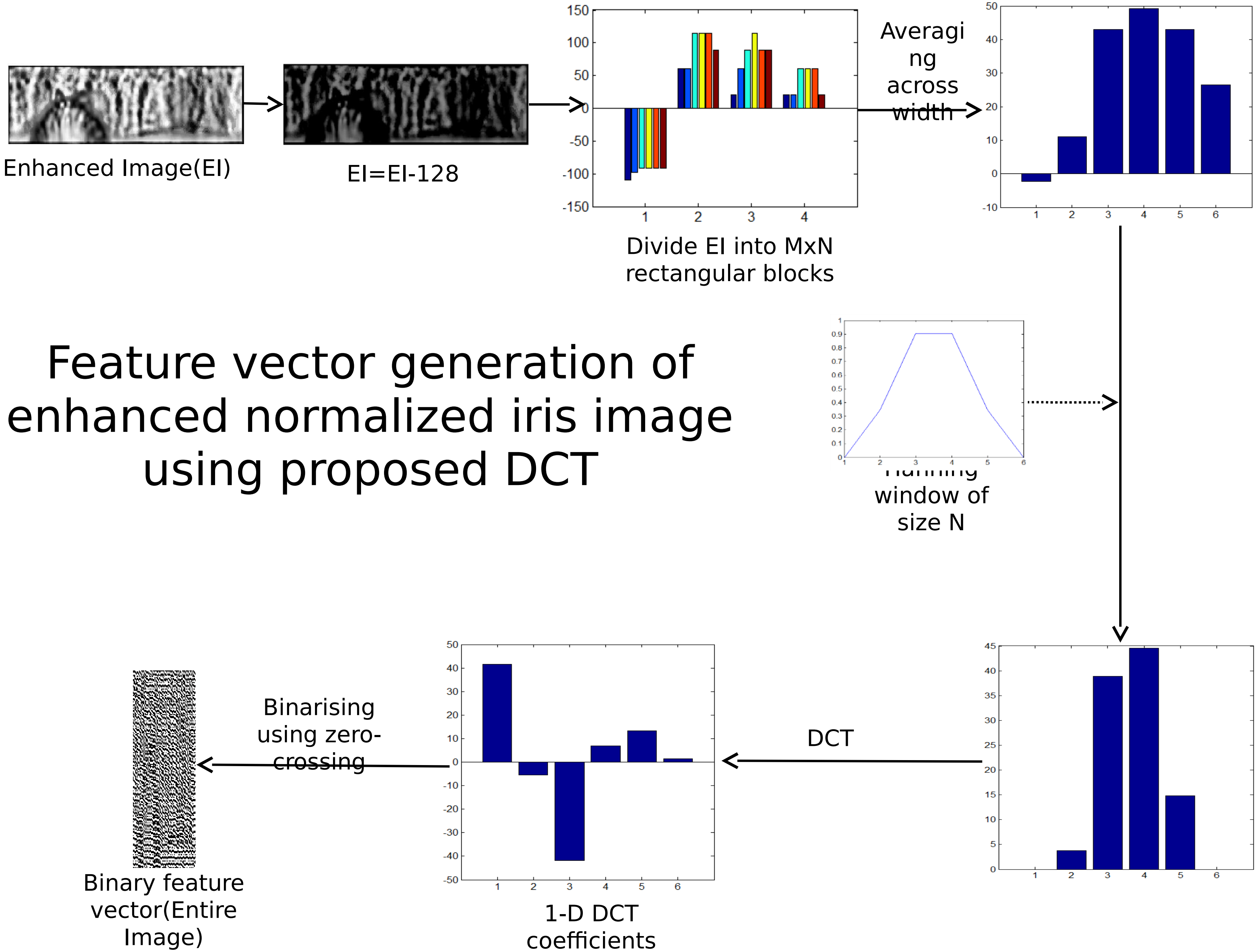
$$R'_j = \sum_{k=1}^{M} R_{j,k} \quad where \ j = 1, 2, \ldots, N$$

  - The obtained intensity signal R' is windowed using Hanning window of size N. Averaging across the width alongwith appropriate windowing smoothens the data and mitigates the effects of noise and other image artifacts.
  - 1-D DCT is applied to code the intensity signal.
  - The generated 1-D DCT coefficient matrix CM of each rectangular block is binarized using zero crossing to give a binary sub-feature vector B.

$$B_j = \begin{cases} 1 & if\ CM_j > 0 \\ 0 & otherwise \end{cases}$$

- Calculating second level occlusion mask
  - First the sum is taken across width in the raw occlusion mask. This gives a matrix of size 1 x N.
  - If the sum across width is more than 80% of the size of the width, then the bit for that sum is masked; otherwise it is unmasked.
  - These bits are concatenated vertically to give a sub-mask of size N x 1.
  - This is iterated for all such blocks; concatenating all such sub-features gives a resultant second-level occlusion mask.

Feature vector generation of enhanced normalized iris image using proposed DCT



Feature Extraction using RM [7]

- Relational Measures are features which are based on relational operators like <, > and =.
- Based on finding the relative difference between the two quantities.
- Vertically and horizontally overlapping regions are chosen from the enhanced normalized image.
- A central region of size b x b is chosen. Its four neighboring regions of same size is taken but at a particular distance d, where d>b.
- A symmetric 2-D Gaussian filter centrally clipped to size b x b is put and convoluted over each of these five regions.
- The response of central region is compared to each of its neighboring regions. If the response of central region is greater than its neighbor, then the bit is encoded as 1, otherwise it is set to 0. In this way, four bits of code are obtained for each central region named as RM bits.
- If the central block has more than 80% of the occluded pixels, then the RM bits for that block are masked; otherwise unmasked.

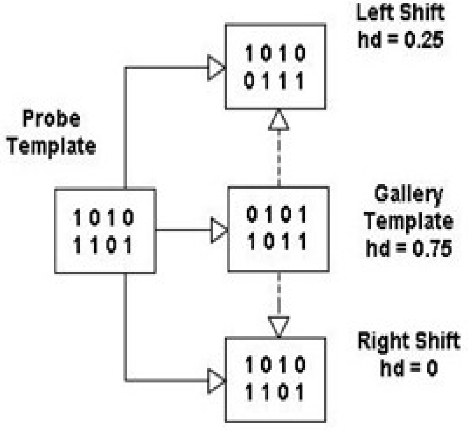
Matching

- The feature vector templates and corresponding second level occlusion masks are used in matching.
- Matching between two iris images takes their respective feature vector templates and second level occlusion masks and calculates the dissimilarity score between the images.
- The dissimilarity score is calculated using hamming distance metric.

$$h_{dist}(t_1, t_2, o_1, o_2) = \frac{\sum_{i=1}^{X} \sum_{j=1}^{Y} [t_1(i,j) \oplus t_2(i,j)] \,|\, [o_1(i,j) + o_2(i,j)]}{X \times Y - \sum_{i=1}^{X} \sum_{j=1}^{Y} [o_1(i,j) + o_2(i,j)]}$$

- Robustness against rotation is also considered to account for head tilting while acquiring image.
- Rotation of the eye in Cartesian coordinate-space corresponds to horizontal translation in the normalized image

- When a probe template is matched with a gallery template, the gallery template is circularly shifted in horizontal direction to get the minimum hamming distance which is taken as the final dissimilarity score.
- When gallery template is rotated, its corresponding second level mask is also rotated.

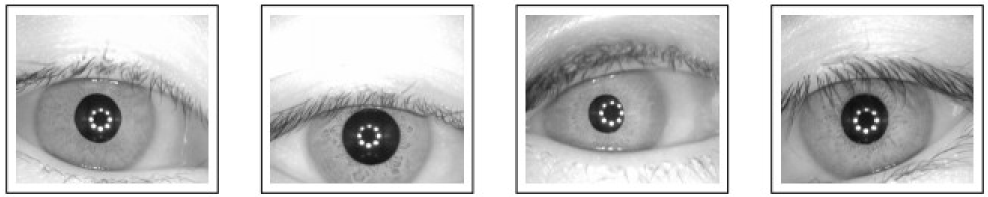


Calculation of minimum Hamming Distance

Specifications of Database

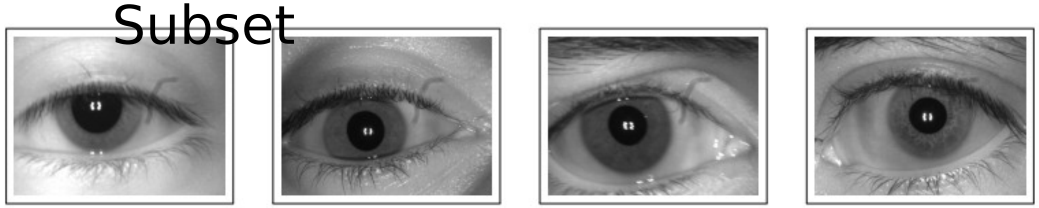
Database		CASIA-4.0 Interval	CASIA-4.0 Lamp	IITK
Size		2639	16,212	20,420
Subjects		249	411	1,021
Sessions		2	1	2
Gallery	Per subject	First 3	First 10	5 images of first session
	Total	1,047	7,830	10,210
Probe	Per subject	Rest	Last 10	5 images of second session
	Total	1,508	7,830	10,210

Database Images



Images from CASIA 4.0-Interval Subset

Images from CASIA 4.0-Lamp Subset



Images from IITK Database

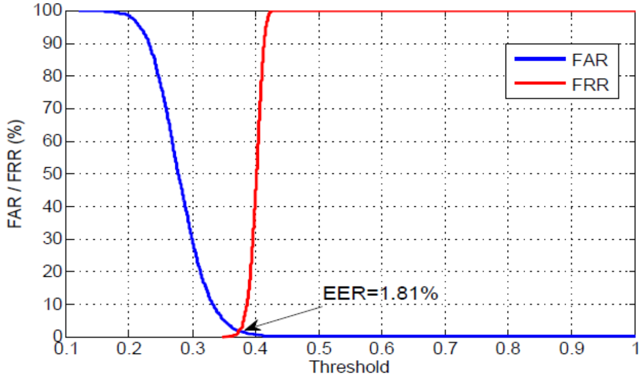
Recognition Results using DCT Feature Extraction Technique

Database	Block-size	CRR (%)	EER (%)
CASIA-4.0 Interval	2x4	99.40	1.81
CASIA-4.0 Lamp	4x8	98.69	3.89
IITK	2x6	98.46	2.07

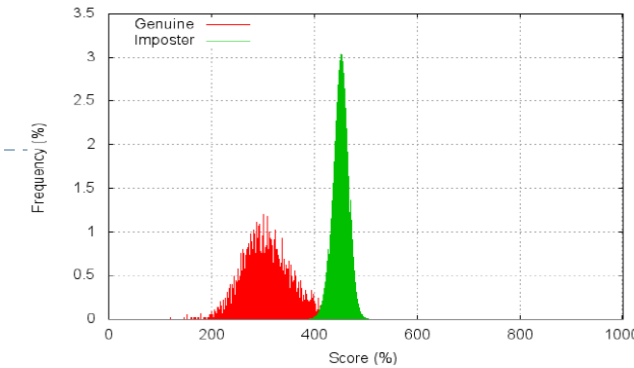
Recognition Performance on Various Databases

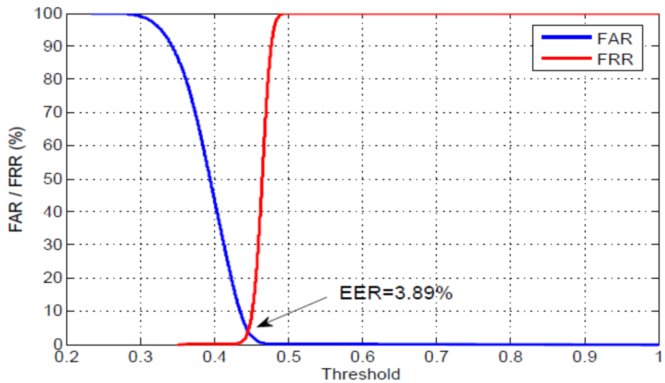
- EER for Lamp is poor than other databases because of heavy occlusion in Lamp database

EER-Equal Error Rate
CRR-Correct Recognition Rate

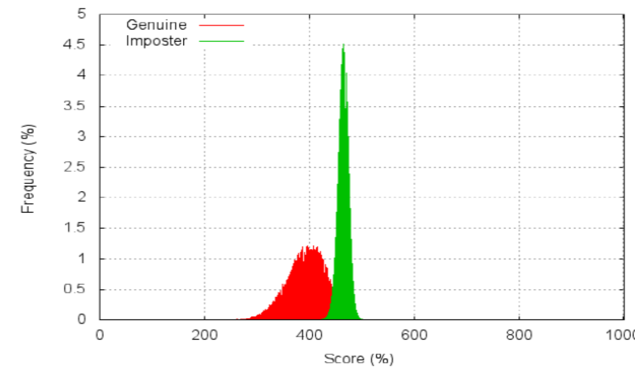


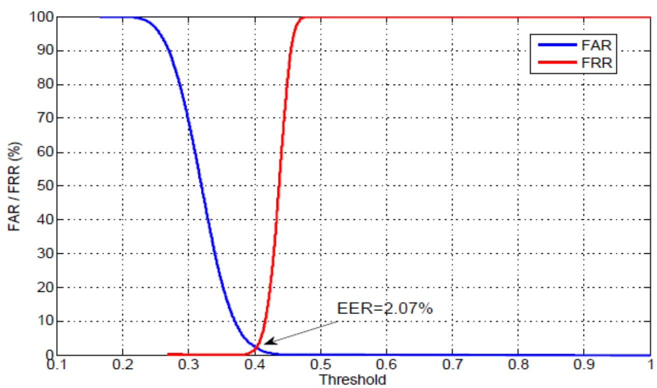
CASIA-4.0
Interval



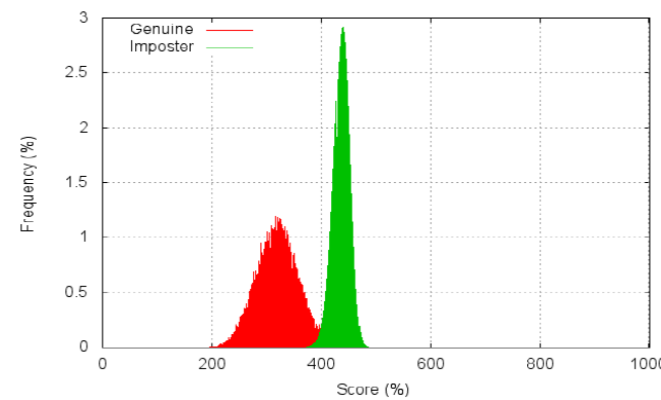


CASIA-4.0
Lamp





IITK
Database

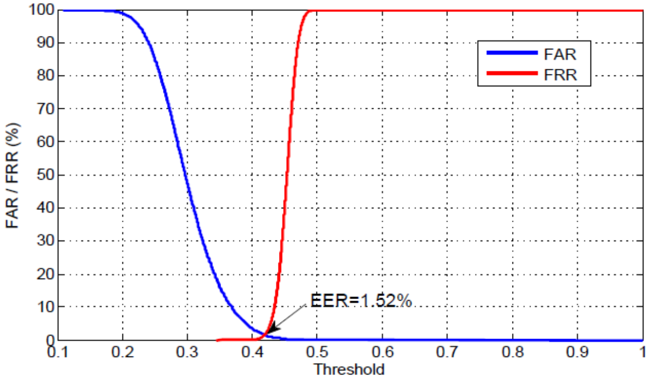


ROC Curves

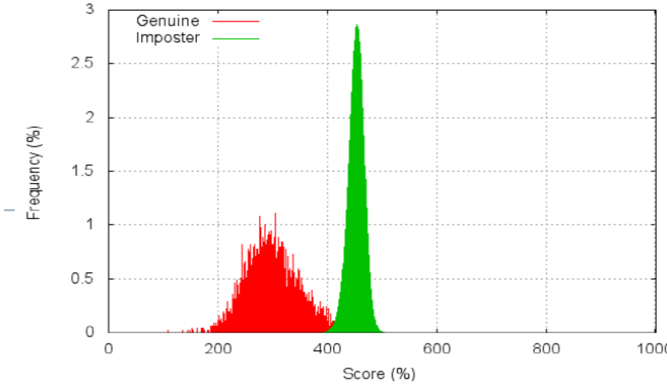
Genuine-Impostor
Frequency
Histogram

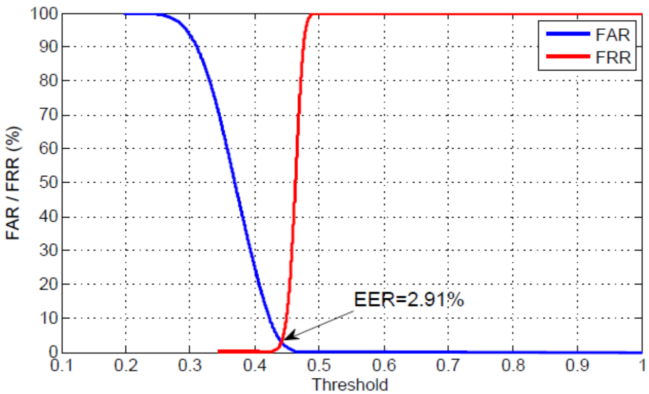
Recognition Results using Score-level Fusion of Proposed DCT and Existing RM Approaches

Database	Proposed DCT		Existing RM [7]		Weightage		Fused(DCT and RM)	
	CRR(%)	EER(%)	CRR(%)	EER(%)	DCT	RM	CRR(%)	EER(%)
CASIA-4.0 Interval	99.40	1.81	99.07	2.26	0.75	0.25	99.40	1.52
CASIA-4.0 Lamp	98.69	3.89	98.69	4.21	0.72	0.28	98.91	2.91
IITK	98.46	2.07	98.66	2.12	0.60	0.40	98.92	1.52

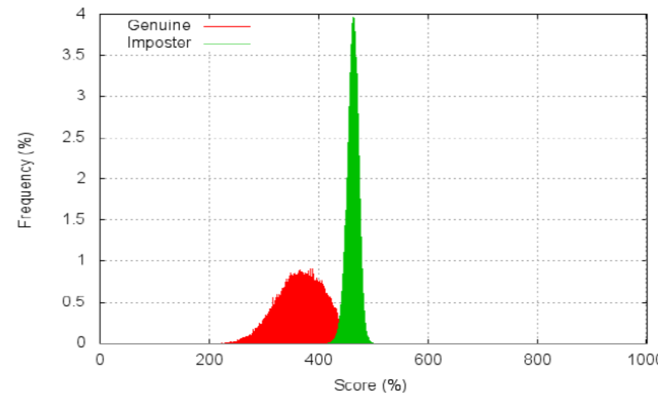


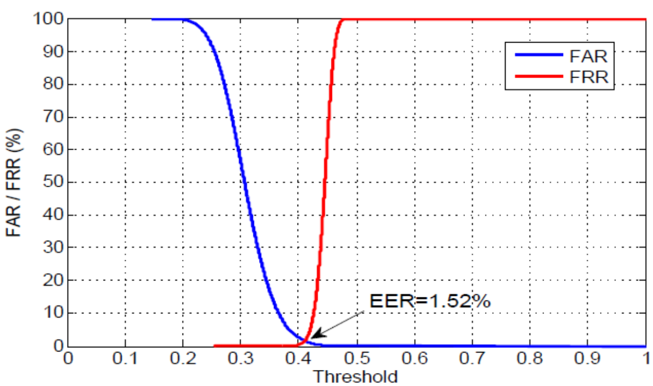
CASIA-4.0
Interval



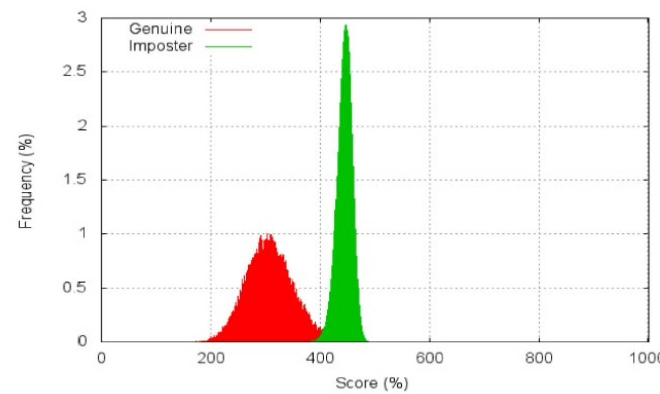


CASIA-4.0
Lamp





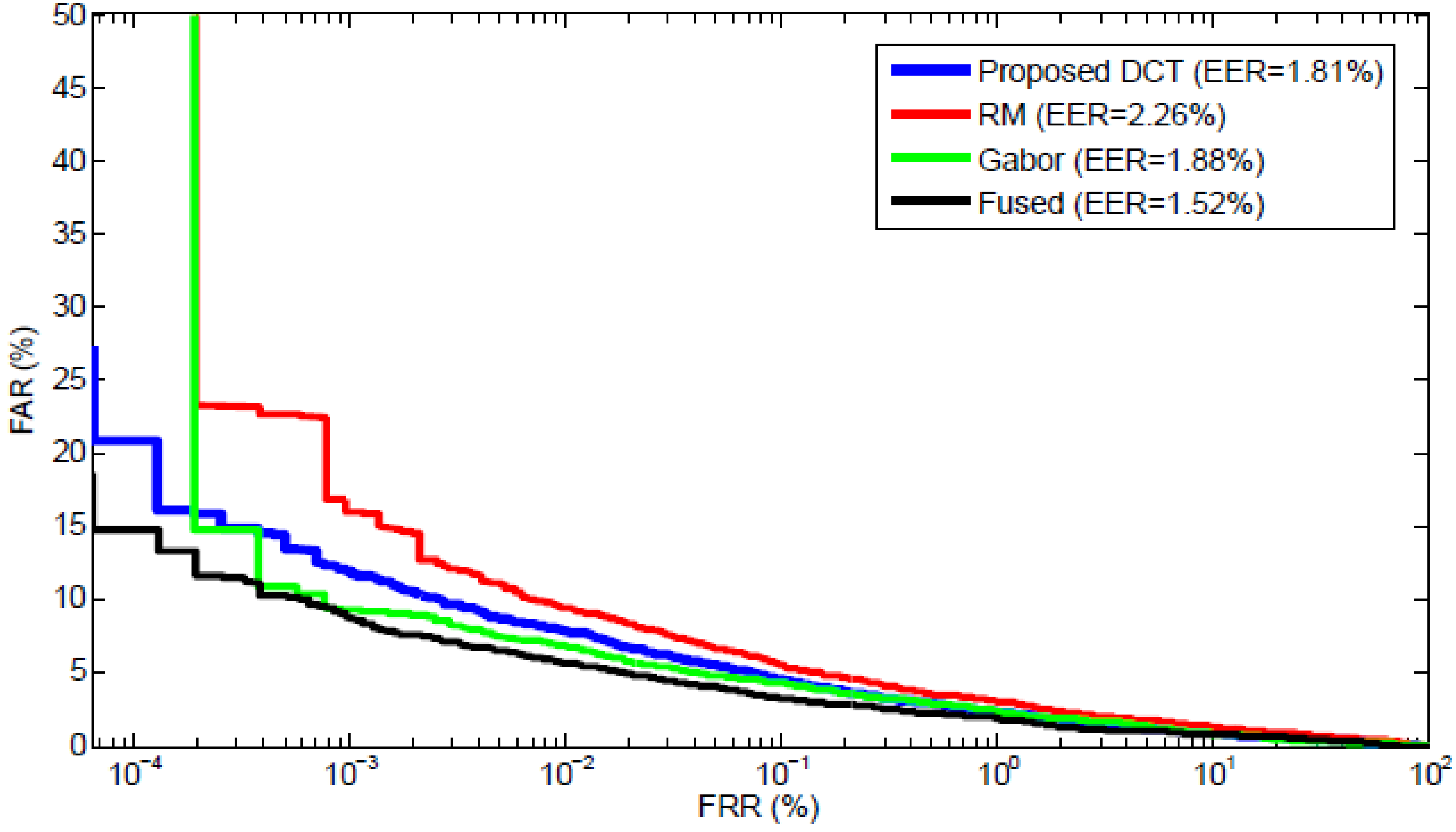
IITK
Database



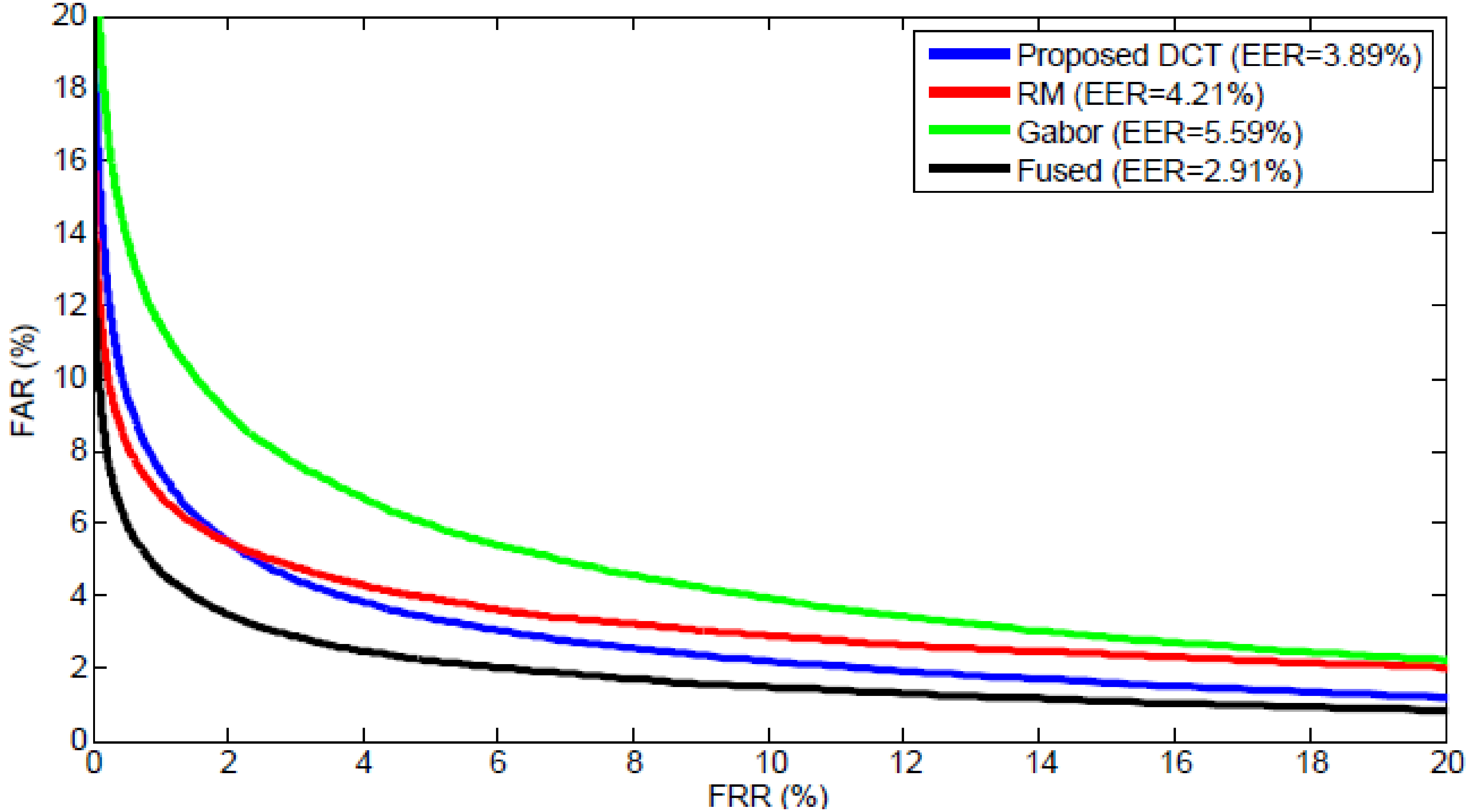
ROC Curves

Genuine-Impostor
Frequency
Histogram

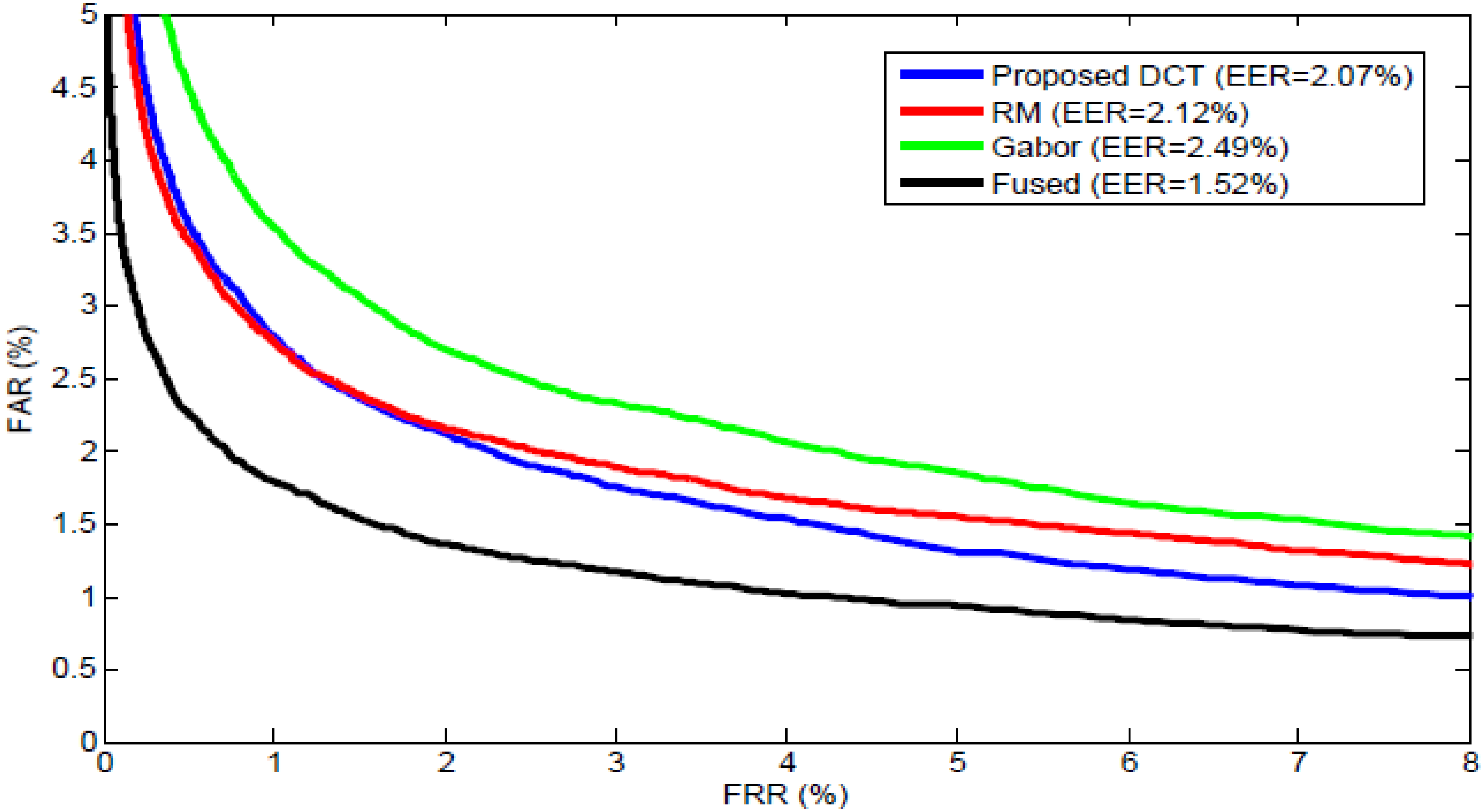
Performance Comparison on Interval Database



Performance Comparison on Lamp Database



Performance Comparison on IITK Database

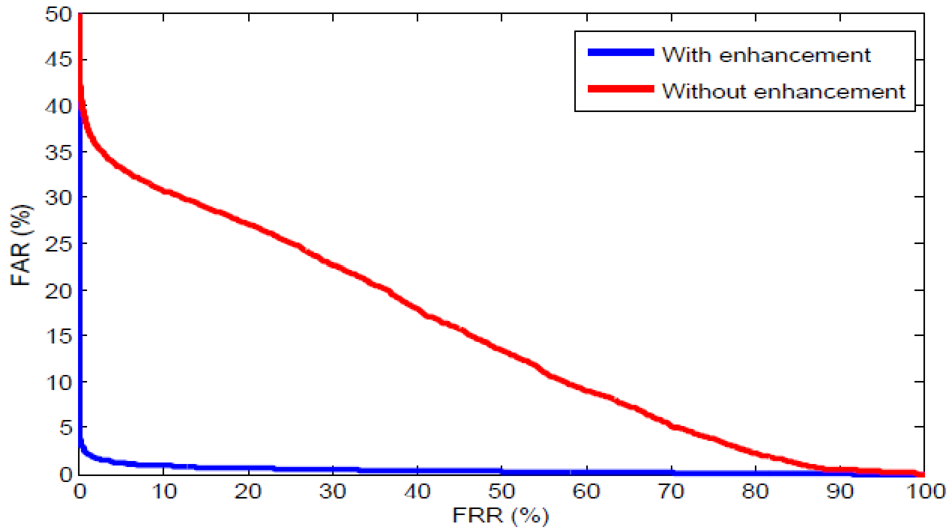


Effect of Enhancement

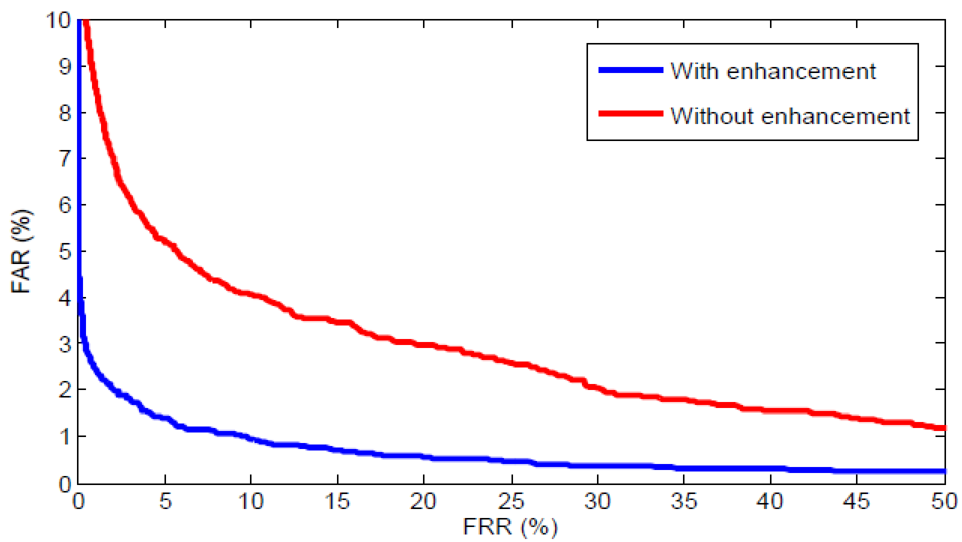
- In enhancement technique, the normalized image is smoothened using average filter and the non-uniform illumination is removed after which CLAHE is applied to enhance the contrast of the image.

Approach	Without Enhancement		With Enhancement	
	CRR(%)	EER(%)	CRR(%)	EER(%)
Proposed DCT	91.97	25.09	99.40	1.81
Gabor-Filtering	98.67	5.17	99.13	2.03

Recognition Performance of approaches on effect of enhancement on CASIA-4.0 Interval



Effect of Enhancement on Proposed DCT on CASIA 4.0 Interval



Effect of Enhancement on Gabor-Filtering on CASIA 4.0 Interval

Conclusions

- The proposed DCT feature extraction approach has obtained CRR of 99.40% on CASIA-4.0 Interval database, 98.69% on CASIA-4.0 Lamp database and 98.46% on IITK database.
- CRR becomes 100% if top ten matches are considered for identification instead of top one.
- The EER of the proposed DCT technique are 1.81% on CASIA-4.0 Interval database, 3.89% on CASIA-4.0 Lamp database and 2.07% on IITK database.

Database	Proposed DCT		Existing RM		Weightage		Fused(DCT and RM)	
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Future Work

- The proposed system can be made robust to handle severe occlusion due to reflection.
- System can be made robust to wearing of contact lenses.
- The system can be made to deal with off-angle and motion-blurred images.
- Feature extraction technique can be applied to only highly discriminative regions of iris instead of whole iris image to decrease time as well as to improve identification accuracy.
- Keypoints of iris images can handle the wrong segmentation and other image artifacts.

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Thank You