

Rowan University

## Rowan Digital Works

---

Henry M. Rowan College of Engineering Faculty  
Scholarship

Henry M. Rowan College of Engineering

---

6-14-2015

# Design and Performance Evaluation of a Biometric Iris Verification System

Ravi Ramachandran  
*Rowan University*

Liang Hong  
*Tennessee State University*

Sachin Shetty  
*Old Dominion University*

Kevin Dahm  
*Rowan University*

Richard Kozick  
*Bucknell University*

*See next page for additional authors*

Follow this and additional works at: [https://rdw.rowan.edu/engineering\\_facpub](https://rdw.rowan.edu/engineering_facpub)



Part of the [Biomedical Engineering and Bioengineering Commons](#), and the [Engineering Education Commons](#)

---

### Recommended Citation

Ramachandran, R. P., Hong, L., Shetty, S., Dahm, K. D., Kozick, R. J., Nickel, R. M., Polikar, R., Tang, Y., & Chin, S. H. (2015). *Design and Performance Evaluation of a Biometric Iris Verification System* Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.23796

This Conference Paper is brought to you for free and open access by the Henry M. Rowan College of Engineering at Rowan Digital Works. It has been accepted for inclusion in Henry M. Rowan College of Engineering Faculty Scholarship by an authorized administrator of Rowan Digital Works.

---

**Authors**

Ravi Ramachandran, Liang Hong, Sachin Shetty, Kevin Dahm, Richard Kozick, Robert Nickel, Robi Polikar, Ying Tang, and Steven Chin



## DESIGN AND PERFORMANCE EVALUATION OF A BIOMETRIC IRIS VERIFICATION SYSTEM

### Dr. Ravi P. Ramachandran, Rowan University

Ravi P. Ramachandran received the B. Eng degree (with great distinction) from Concordia University in 1984, the M. Eng degree from McGill University in 1986 and the Ph.D. degree from McGill University in 1990. From October 1990 to December 1992, he worked at the Speech Research Department at AT&T Bell Laboratories. From January 1993 to August 1997, he was a Research Assistant Professor at Rutgers University. He was also a Senior Speech Scientist at T-Netix from July 1996 to August 1997. Since September 1997, he is with the Department of Electrical and Computer Engineering at Rowan University where he has been a Professor since September 2006. He has served as a consultant to T-Netix, Avenir Inc., Motorola and Focalcool. From September 2002 to September 2005, he was an Associate Editor for the IEEE Transactions on Speech and Audio Processing and was on the Speech Technical Committee for the IEEE Signal Processing society. Since September 2000, he has been on the Editorial Board of the IEEE Circuits and Systems Magazine. Since May 2002, he has been on the Digital Signal Processing Technical Committee for the IEEE Circuits and Systems society. His research interests are in digital signal processing, speech processing, biometrics, pattern recognition and filter design.

### Dr. Liang Hong, Tennessee State University

Dr. Liang Hong received the B.S. and the M.S. degrees in Electrical Engineering from Southeast University, Nanjing, China in 1994 and 1997, respectively, and the Ph.D. degree in Electrical Engineering from University of Missouri, Columbia, Missouri in 2002. Since August 2003, he has been with the Department of Electrical & Computer Engineering at Tennessee State University where he is now Full Professor. His research interests include cognitive radio, modulation classification, wireless multimedia communications, and engineering education.

### Dr. Sachin Shetty, Tennessee State University

Sachin Shetty is currently an Assistant Professor in the Department of Electrical and Computer Engineering at Tennessee State University. He received his Ph.D. degree in Modeling and Simulation from Old Dominion University in 2007 under the supervision of Prof. Min Song. His research interests lie at the intersection of computer networking, network security and machine learning. Recently, he has been working on security issues in cloud computing, cognitive radio networks, and wireless sensor networks. Over the years, he has secured funding over \$3 million from NSF, AFOSR, DOE, DHS, TBR and local industry for research and educational innovations. He has authored and coauthored over 30 technical refereed and non-refereed papers in various conferences, international journal articles, book chapters in research and pedagogical techniques. He is the director of the Cyber Defense and Security Visualization Laboratory

### Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is a Professor of Chemical Engineering at Rowan University. He earned his BS from Worcester Polytechnic Institute (92) and his PhD from Massachusetts Institute of Technology (98). He has published two books, "Fundamentals of Chemical Engineering Thermodynamics" and "Interpreting Diffuse Reflectance and Transmittance." He has also published papers on effective use of simulation in engineering, teaching design and engineering economics, and assessment of student learning.

### Dr. Richard J. Kozick, Bucknell University

Richard J. Kozick received the B.S. degree from Bucknell University in 1986, the M.S. degree from Stanford University in 1988, and the Ph.D. degree from the University of Pennsylvania in 1992, all in electrical engineering. From 1986 to 1989 and from 1992 to 1993 he was a Member of Technical Staff at AT&T Bell Laboratories. Since 1993, he has been with the Electrical and Computer Engineering Department at Bucknell University, where he is currently Professor. His research interests are in the areas of statistical signal processing and communications.



Dr. Kozick received a "2006 Best Paper Award" from the IEEE Signal Processing Society and the Presidential Award for Teaching Excellence from Bucknell University in 1999. He serves on the editorial boards of the Journal of the Franklin Institute and the EURASIP Journal on Wireless Communications and Networking.

**Prof. Robert M Nickel, Bucknell University**

Robert M. Nickel received a Dipl.-Ing. degree in electrical engineering from the RWTH Aachen University, Germany, in 1994, and a Ph.D. in electrical engineering from the University of Michigan, Ann Arbor, Michigan, in 2001. During the 2001/2002 academic year he was an adjunct faculty in the Department of Electrical Engineering and Computer Science at the University of Michigan. From 2002 until 2007 he was a faculty member at the Pennsylvania State University, University Park, Pennsylvania. Since the fall of 2007 he is a faculty member at the Electrical Engineering Department of Bucknell University, Lewisburg, Pennsylvania. During the 2010/2011 academic year he was a Marie Curie Incoming International Fellow at the Institute of Communication Acoustics, Ruhr-Universität Bochum, Germany. His main research interests include speech signal processing, general signal theory, and time-frequency analysis.

**Dr. Robi Polikar, Rowan University**

Robi Polikar is a Professor of Electrical and Computer Engineering at Rowan University, in Glassboro, NJ. He has received his B.Sc. degree in electronics and communications engineering from Istanbul Technical University, Istanbul, Turkey in 1993, and his M.Sc and Ph.D. degrees, both co-majors in electrical engineering and biomedical engineering, from Iowa State University, Ames, IA in 1995 and 2000, respectively. His current research interests within computational intelligence include ensemble systems, incremental and nonstationary learning, and various applications of pattern recognition in bioinformatics and biomedical engineering. He is a member of IEEE, ASEE, Tau Beta Pi and Eta Kappa Nu. His recent and current works are funded primarily through NSF's CAREER and Energy, Power and Adaptive Systems (EPAS) programs.

**Dr. Ying Tang, Rowan University**

Ying Tang received the B.S. and M.S. degrees from the Northeastern University, P. R. China, in 1996 and 1998, respectively, and Ph.D degree from New Jersey Institute of Technology, Newark, NJ, in 2001. She is currently a Professor of Electrical and Computer Engineering (ECE) at Rowan University, Glassboro, NJ. Her research interests include virtual reality and augmented reality, artificial intelligence, and modeling and scheduling of computer-integrated systems. Dr. Tang is very active in adapting and developing pedagogical methods and materials to enhance engineering education. Her most recent educational research includes the collaboration with Tennessee State University and local high schools to infuse cyber-infrastructure learning experience into the pre-engineering and technology-based classrooms, the collaboration with community colleges to develop interactive games in empowering students with engineering literacy and problem-solving, the integration of system-on-chip concepts across two year Engineering Science and four year ECE curricula, and the implementation of an educational innovation that demonstrates science and engineering principles using an aquarium. Her work has resulted in over 100 journal and conference papers and book chapters.

**Dr. Steven H Chin, Rowan University**

Steven H. Chin is currently the Associate Dean of Engineering at Rowan University. He has been in this position since 1997, while serving as Interim Dean from 2010-2012. He has a Bachelor of Science in Electrical Engineering and Ph.D. from Rutgers University, and Masters of Science in Electrical Engineering from the Johns Hopkins University. His specialization areas are in signal processing and communication system. His current interests include STEM education, and academic partnerships.

# **DESIGN AND PERFORMANCE EVALUATION OF A BIOMETRIC IRIS VERIFICATION SYSTEM**

## **ABSTRACT**

This paper describes an iris verification project focused on design and performance evaluation under both matched and mismatched training and testing conditions. Training is always performed on clean iris images. Testing is performed on both clean and noisy iris images. This project is part of a senior undergraduate course on biometric systems. In implementing an iris recognition system, students go through each step, namely, preprocessing, feature extraction, classification (training and use in rendering a decision) and performance evaluation. The Chinese Academy of Sciences - Institute of Automation (CASIA) eye image database known as the CASIA-Iris-Interval-v3 database is used to show students that robustness to mismatched training and testing conditions is a significant practical issue.

## INTRODUCTION AND MOTIVATION

Biometrics is the science of recognizing and authenticating people using their physiological features. Border and immigration control, restricted access to facilities and information systems, cybersecurity, criminal investigations and forensic analysis are just a few of the primary application areas of biometrics used by commercial, government and law enforcement agencies. There is much research interest in different biometric systems, notably, iris recognition.

Two important applications of iris recognition include airport security, for recognizing passengers, employees and flight crews and especially for matching an individual against a watch list [1]. The second is for recognition in a coal mine where face and fingerprint modalities may not provide adequate image quality due to the working conditions [1]. In this case, iris recognition can supplement the face and fingerprint modalities. Other applications of iris recognition include physical access control, internet security, forensics, electronic commerce, the transportation industry and automobile ignition and unlocking as an anti-theft measure.

The advantages of iris recognition are [1][2][3]:

- **Permanence:** The unique features of the iris are formed by 10 months of age and change very little over a person's lifetime. Subjects need only to be trained once during an entire lifetime. Face, signature and speech features are not permanent and change as a person advances in age.
- **Unique:** The probability of the irises of two different people being the same or resulting in the same biometric features is nearly impossible. The irises of twins can be distinguished.
- **Easy integration:** Iris recognition technology can easily be integrated into existing security systems or operate as a standalone. No special purpose hardware other than a simple Web camera is needed for integration to a personal computer. This is also true of speech and face based systems.
- **Cannot be spoofed:** The iris images or features are not susceptible to theft, loss or compromise. They cannot be artificially duplicated. This is not true of the face, speech and fingerprint modalities that can be spoofed.
- **Non-Invasive and Quick:** Iris recognition does not involve any contact and is quick to give a result. The verification time is a few seconds. This is also true of face, speech and fingerprint systems.
- **Very high accuracy** making it a method of choice for airport security and other biometrics applications.

Disadvantages of iris recognition exist but are becoming less of an issue [1][2][3]:

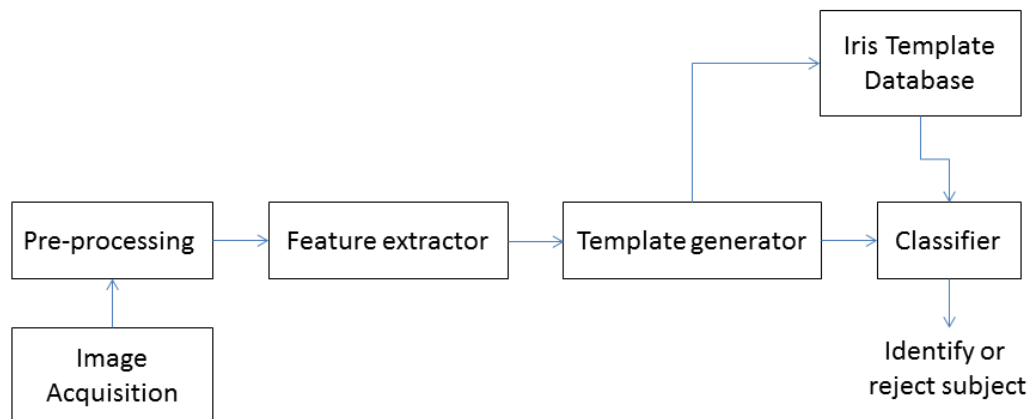
- Much memory required for data to be stored.
- Very expensive, but the cost is coming down.
- User acceptance is low but becoming better.
- There is performance degradation due to mismatched training and testing conditions. This is an issue that also affects speech, fingerprint and face based systems and is a very important area of biometrics research.

The motivation of the work presented in this paper is to make students aware of the performance degradation due to mismatched training and testing conditions in iris verification. In [4], the effects of image compression on iris verification are studied. Another type of mismatched condition occurs when the gaze is different between training and testing [1]. In this paper, the Iriscode algorithm [5] and its associated MATLAB code [6] is used as a starting point. The task is for students to simulate communication channel errors at various bit rates and observe the effects on iris recognition performance. Training is performed on clean iris images.

The assessment results are based on faculty formulated rubrics.

## IRIS RECOGNITION SYSTEM

Figure 1 shows the block diagram of the iris recognition system [4].



**Figure 1. Block diagram of the iris recognition system**

In general, an iris recognition system consists of six components:

1. An image acquisition system that collects and converts the eye image to digital format.

2. Pre-processing algorithms that remove artifacts from the digital output obtained from the image acquisition system. These algorithms usually enhance, segment, and normalize the digital images.
3. A feature extractor that extracts significant features.
4. A template generator that generates a template, which provides a discriminating representation of the features.
5. A storage component, i.e. the database that stores the templates.
6. A classifier that compares the generated template with the other stored templates for recognition. This result will be used to identify or reject the subject.

Based on the block diagram shown in Figure 1, several subsystems are needed for the iris recognition system. Since the CASIA eye image database is used in this experiment, the image acquisition subsystem does not need to be developed. The MATLAB-based tools for the other subsystems are publicly available [6]. These include pre-processing with the Hough transform based segmentation and Daugman's rubber sheet model-based normalization, 1-D log-Gabor filter-based feature extraction, bit-wise biometric template generation, and fractional Hamming distance (FHD) calculation between the templates for subject identification. Students have to write their own code to plot the receiver operating characteristic (ROC).

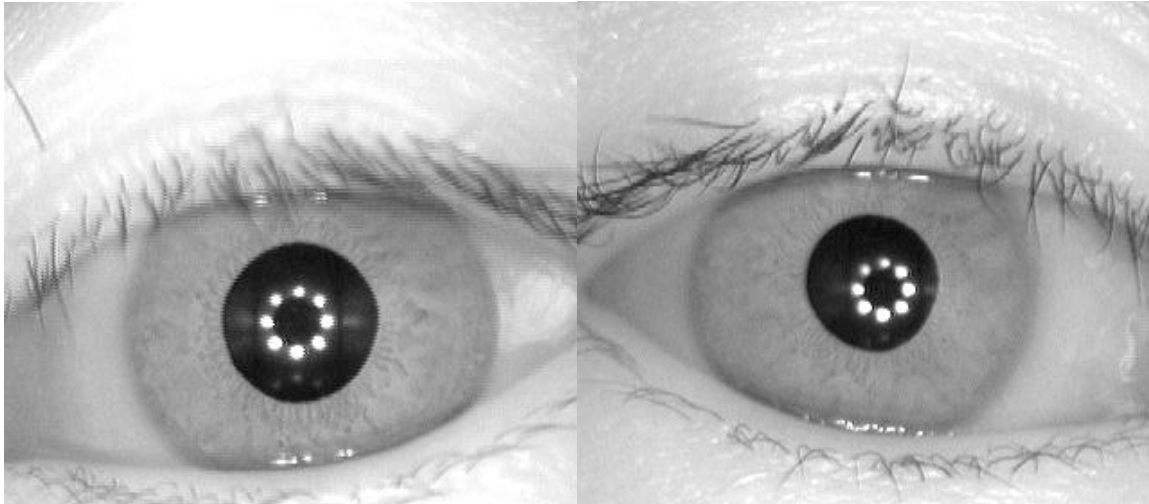
## **DATABASE**

To test the developed iris recognition system, the Chinese Academy of Sciences - Institute of Automation (CASIA) eye image database [7], CASIA-Iris-Interval-v3, was used. This database contains 2,639 greyscale eye images with 395 unique eyes or classes and 5 different images of each unique eye. Images from each class are taken from two sessions with a one month interval between sessions. The images were captured especially for iris recognition research using specialized digital optics developed by the National Laboratory of Pattern Recognition in China. The eye images are mainly from persons of Asian descent, whose eyes are characterized by irises that are densely pigmented, and by dark eyelashes. Due to specialized imaging conditions using near infra-red light, the features in the iris region are highly visible and there is good contrast between pupil, iris and sclera regions.

In the CASIA eye image database, there are 249 subjects (persons). The subdirectories 001 to 249 in the database refer to the subject number. In each subdirectory, there is an information file and two additional subdirectories, namely, L and R. The L refers to iris images of the left eye. The R refers to iris images of the right eye. The filenames are very convenient to interpret. For example, the file S1012R02.jpg is interpreted as follows: The



'S1' is a common prefix for every file. The '012' refers to subject 12. The 'R' refers to an image of the right eye. The '02' refers to image number 2 of the right eye. Note that the number of images is not necessarily the same for each subject. Also, some subjects do not have any left eye images and some subjects do not have any right eye images. For example, subject 22 has no right eye images. Figure 2 shows an example of a left eye and right eye iris image for subject 9.



(a) Left Eye

(b) Right Eye

**Figure 2 – Left Eye and Right Eye Iris Images (S1009L01.jpg and S1009R01.jpg)**

## **LEARNING OUTCOMES**

The student learning outcomes of the project include:

- Enhanced application of math skills
- Enhanced software implementation skills
- Enhanced interest in biometrics
- Enhanced ability to analyze experimental results
- Enhanced communication skills
- Comprehension of the importance of vertical integration in that students realize that their experiences are part of a flow that contributes to a unified knowledge base.

## **SPECIFIC OBJECTIVES OF LABORATORY PROJECT**

The objectives of this experiment are to

- develop and implement an iris recognition system using a standard iris database and open-source tools
- verify its performance with clean eye images

- verify its performance when the images are transmitted over a communication link
- quantitatively evaluate the performance

## **LABORATORY PROTOCOL**

The laboratory protocol includes both supplied MATLAB code and code that has to be written by the student. This experiment is briefly described in [8]. More detail and assessment results are given here. In this experiment, 40 subjects numbered 001 to 040 will be used for iris recognition. Both the left and right eye images for each subject will be used in the experiment. Each student group will implement an iris recognition system using the open-source iris recognition tools and the CASIA eye image database.

This section continues by giving the laboratory instructions as it was presented to the students. The word ‘you’ as used in the laboratory protocol below addresses the student groups. Also, sentences written in the ‘imperative’ format also address the student groups.

A zip file having the CASIA-Irisv3-Interval eye image database and the iris recognition MATLAB based tools will be emailed to you. Upon unzipping the file, there will be a main directory called ‘iris’ which will be referred to as C:\iris (although one can have it on any drive). There will be three subdirectories, namely,

- C:\iris\CASIA-IrisV3-Interval
- C:\iris\FHD\_Results
- C:\iris\utility

Also, the directory C:\iris will have m-files that are to be used. Check that all of these have been obtained.

### **Iris recognition – Generating the Templates**

Set the current folder to C:\iris. The following lists the tasks to be completed.

- Run the MATLAB code ‘iristemplates.m’ to generate templates for all the eye images corresponding to subjects 001 to 040. This includes the templates for the clean iris images (subjects 001 to 040) and the noisy iris images (subjects 021 to 040). Demonstrate your understanding of the code ‘iristemplates.m’ by writing a few sentences about it.
- Examine the templates files and view the iris images (in the CASIA-IrisV3-Interval subdirectory) of several subjects from 001 to 020 (clean images only).

Note that the template files are merely binary files (Iriscode) from which the fractional Hamming distance (FHD) values are calculated. View the iris images of several subjects from 021 to 040 (clean and noisy images).

### **Iris recognition – Training the System on Clean Images**

- Run the MATLAB code 'irisFHDIntraClass.m' (with option = 0) to calculate the FHD between the templates of all pairs of images of the same subject, except of course between two identical images for which the FHD is 0. Using an option of 0 calculates the intraclass FHD for subjects 001 to 020 (training data). The MATLAB code 'gethammingdistance.m' is called by 'irisFHDIntraClass.m'. Demonstrate your understanding of the programs 'irisFHDIntraClass.m' and 'gethammingdistance.m' by writing a few sentences about each. Note that after running this program, the file 'trainingFHDIntraClass.txt' appears in the FHD\_Results subdirectory. This file contains all the obtained FHD values.
- Run the MATLAB code 'irisFHDInterClass.m' (with option = 0) to calculate the FHD between the templates of all pairs of images of different subjects. Using an option of 0 calculates the interclass FHD for subjects 001 to 020 (training data). The MATLAB code 'gethammingdistance.m' is called by 'irisFHDInterClass.m'. Demonstrate your understanding of the program 'irisFHDInterClass.m' by writing a few sentences about it. Note that after running this program, the file 'trainingFHDInterClass.txt' appears in the FHD\_Results subdirectory. This file contains all the obtained FHD values.

- Run the MATLAB code 'irisClassificationThreshold.m' to plot the probability density function (pdf) of the FHD values obtained (both intraclass and interclass). Demonstrate your understanding of the code by writing a few sentences about it. Note that after running this program, the files 'pdfTraining.tif' and 'ThresholdTable.txt' appears in the FHD\_Results subdirectory. Examine the value of the variable BestThreshold and discuss how it was chosen? What information is conveyed in the file 'ThresholdTable.txt' (open using Wordpad)? What do you observe regarding the probability density functions of the intraclass and interclass FHDs?
- Write your own MATLAB program to plot the ROC curve for the training data. Use thresholds from 0.1 to 0.9 in steps of 0.005. Find the best estimate for the Equal Error Rate (EER) of the system. This gives an estimate of the EER for the training data. What threshold results in this EER? Compare the best threshold found for the EER and the Total Error Rate (sum of the False Accept and False Reject rates). Is it fair to compare the EER with the smallest Total Error Rate and the EER or are the two pieces of information essentially different?

The students plot the probability density function of the intraclass and interclass FHD values as a histogram. This plot is shown in Figure 3. There is a clear separation between the two sets of FHDs.

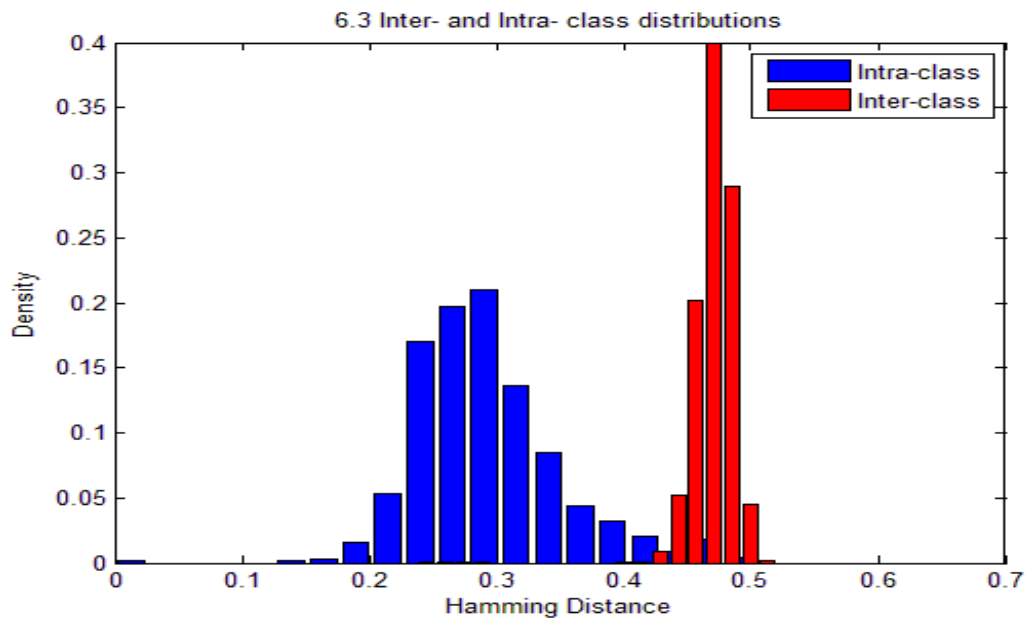


Figure 3 – Intraclass and Interclass Fractional Hamming Distance Histograms

## **Iris recognition – Performance Evaluation on Clean Data Not Part of the Training Set**

- True trials: Run the MATLAB code 'irisFHDIntraClass.m' (with option = 1 and no bit errors) to calculate the intraclass FHD for subjects 021 to 040 (clean test data). Note that after running this program, the file EvaluationFHDIntraClass.txt appears in the FHD\_Results subdirectory. What does this file contain?
- Impostor trials: Run the MATLAB code 'irisFHDInterClass.m' (with option = 1 and no bit errors) to calculate the interclass FHD for subjects 021 to 040 (clean test data). Note that after running this program, the file EvaluationFHDInterClass.txt appears in the FHD\_Results subdirectory. What does this file contain?
- Plot the probability density function of the intraclass and interclass FHD values obtained. How does it compare to the plot resulting in the previous case (Figure 3). Comment on the differences.
- In this step, it is assumed that the threshold is picked for the best Total Error Rate from the training data (subjects 1 to 20). For the evaluation data (subjects 21 to 40), what is the false accept rate (FAR), false reject rate (FRR) and Total Error Rate for the BestThreshold found for the training data? Compare with the previous results.
- In this step, it is assumed that the threshold that led to the EER from the training data (subjects 1 to 20) is picked for the evaluation data. For the evaluation data (subjects 21 to 40), what are the FAR, FRR for this threshold? Compare with the previous results.
- Write your own MATLAB program to plot the ROC curve for the clean evaluation data. Use thresholds from 0.1 to 0.9 in steps of 0.001. Find the best estimate for the Equal Error Rate (EER) of the system? This gives an estimate of the EER for the evaluation test data. Compare the EER with that found for the training data.

## **Iris recognition – Performance Evaluation on Data Corrupted by Bit Errors**

- Follow the relevant steps to calculate the intraclass FHD, interclass FHD for the clean evaluation data (subjects 021 to 040) corrupted by communication distortion corresponding to bit error rates of  $1e-07$ ,  $1e-03$  and  $1e-01$ . The iris images for these bit error rates are noisy and have been configured earlier.
- Write your own MATLAB program to plot the ROC curve for the clean evaluation data corrupted by communication distortion corresponding to bit error rates of  $1e-07$ ,  $1e-03$  and  $1e-01$ . Use thresholds from 0.1 to 0.9 in steps of 0.001. Compare the EER for the three bit error rates and with those that were found for the clean data? How does the performance of the system compare for clean and noisy iris images?

### ASSESSMENT RESULTS

Rubrics used to quantify student achievement of project instructional outcomes were developed. For each instructional outcome, four levels of achievement were designated. A score of 1 to 4 was given based on the project lab report. The advantages of using rubric based assessment are that it gives a quantitative judgment of student knowledge, requires little extra work in the grading process, requires no additional training for faculty to use, and avoids complete reliance on student self-reporting through surveys [9][10]. Table 1 gives the outcomes and levels of achievement for the iris verification project. Table 2 gives the statistics.

Indicator	4	3	2	1
Students are able to (1) train the system on clean images, (2) understand the supplied MATLAB code and (3) plot and interpret the probability density functions for the intraclass and interclass FHDs.	All the work was done correctly.	The supplied MATLAB code was run and interpreted correctly. There are minor mistakes in the interpretation of the probability density functions.	The supplied MATLAB code was run and interpreted correctly. There are major mistakes in the interpretation of the probability density functions..	The work had many major mistakes.
Students were able to write MATLAB code to plot an ROC curve and determine	All work was done correctly.	The code was written and the EER was determined	There were mistakes either in the MATLAB	Students did not attempt this.

the EER correctly for the cases of clean images both part and not part of the training set.		but no explanation of the results given.	code and/or determination of the EER.	
Students were able to write MATLAB code to plot an ROC curve and determine the EER correctly for the cases of images corrupted by bit errors.	All work was done correctly.	The code was written and the EER was determined but no explanation of the results given.	There were mistakes either in the MATLAB code and/or determination of the EER.	Students did not attempt this.

**Table 1 – Rubrics for Iris Verification Project**

Outcome	Mean, Median
Training and probability density function	3.88, 4
ROC and EER for clean data	3.63, 4
ROC and EER for data corrupted by bit errors	3.52, 4.

**Table 2 – Rubric Statistics**

## SUMMARY AND CONCLUSIONS

This lab project was successful in teaching the basic principles of biometric verification using the iris as the modality and enabling the students to understand that an important issue in iris recognition is the mismatch between training and testing conditions.

## ACKNOWLEDGEMENT

This work was supported by the National Science Foundation through TUES Type 2 Collaborative Research Grants DUE-1122296, DUE-1122344 and DUE-1122299. The authors thank the Chinese Academy of Sciences for donating the (CASIA) eye image database that is used in this study. The authors also thank Libor Masek and Peter Kovsesi for making available the MATLAB code for the iris recognition algorithm freely available on the Web [6].

## REFERENCES

1. A. K. Jain, A. A. Ross and K. Nandakumar, Introduction to Biometrics, Springer, 2011.

2. <http://www.irisid.com/irisrecognitiontechnology>
3. [http://www.slideshare.net/ajinkya\\_93/iris-recognition-seminar](http://www.slideshare.net/ajinkya_93/iris-recognition-seminar)
4. R. W. Ives, B. L. Bonney and D. M. Etter, “Effect of Image Compression on Iris Recognition”, IEEE Instrumentation and Measurement Technology Conference, Ottawa, Canada, May 17—19, 2005.
5. J. Daugman, “How Iris Recognition Works”, IEEE Transactions on Circuits and Systems for Video Technology, Vol. 14, No. 1, pp. 21—30, 2004.
6. Libor Masek, Peter Kovesi. *MATLAB Source Code for a Biometric Identification System Based on Iris Patterns*. The School of Computer Science and Software Engineering, The University of Western Australia. 2003. (see also <http://www.csse.uwa.edu.au/~pk/studentprojects/libor/sourcecode.html>)
7. Biometric Ideal Test, “Note on CASIA-IrisV3,” <http://biometrics.idealtest.org/dbDetailForUser.do?id=3>, .
8. R. P. Ramachandran, K. D. Dahm, R. Nickel, R. Kozick, S. S. Shetty, L. Hong, S. H. Chin, R. Polikar and Y. Tang, “Vertical Integration of Biometrics Across the Curriculum: Case Study of Speaker, Face and Iris Recognition”, *IEEE Circuits and Systems Magazine*, Vol. 14, No. 3, pp. 55—69, September 2014.
9. J. A. Newell, H. L. Newell and K. D. Dahm, “Rubric Development and Inter-Rater Reliability Issues in Assessing Learning Outcomes”, *Chemical Engineering Education*, Summer 2002.
10. J. A. Newell, H. L. Newell and K. D. Dahm, “Rubric Development for Assessment of Undergraduate Research: Evaluating Multidisciplinary Team Projects”, *Chemical Engineering Education*, 2003.