AC 2012-3281: PROJECT-BASED DESIGN OF A BIOMETRIC FACE RECOGNITION 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 Oct. 1990 to Dec. 1992, he worked at the Speech Research Department at AT&T Bell Laboratories. From Jan. 1993 to Aug. 1997, he was a Research Assistant Professor at Rutgers University. He was also a Senior Speech Scientist at T-Netix from July 1996 to Aug. 1997. Since Sept. 1997, he has been with the Department of Electrical and Computer Engineering at Rowan University where he has been a professor since Sept. 2006. He has served as a consultant to T-Netix, Avenir Inc., and Motorola. From Sept. 2002 to Sept. 2005, he was an Associate Editor for the IEEE Transactions on Speech and Audio Processing and was on the Speech Technical Committee of the Signal Processing society. Since Sept. 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 Circuits and Systems society. His research interests are in digital signal processing, speech processing, pattern recognition, and filter design.

Dr. Robi Polikar, Rowan University

Robi Polikar received his Ph.D. from Iowa State University in Ames, Iowa in 2000 in electrical engineering and biomedical engineering. He is a Professor of electrical and computer engineering at Rowan University, Glassboro, N.J., where he chairs the department and also directs the Signal Processing and Pattern Recognition Laboratory. His recent and current works are funded primarily through National Science Foundation's CAREER and Energy, Power, and Adaptive Systems programs. His primary research interests encompass various related areas of computational intelligence, neural networks, and learning systems, including ensemble based learning, incremental and nonstationary learning, data and decision fusion, and their real-world applications, in which he has more than 120 peer-reviewed publications. He is also interested in developing educational paradigms that allow undergraduate and entry-level graduate students to participate in rigorous computational intelligence research. Polikar is an Associate Editor of IEEE Transactions on Neural Networks and Learning Systems.

Dr. Kevin D. Dahm, Rowan University

Kevin Dahm is an Associate Professor of chemical engineering at Rowan University. He received his B.S. from WPI in 1992 and his Ph.D. from MIT in 1998, and joined Rowan in 1999. He has received the Joseph J. Martin Award, the Raymond W. Fahien Award, the PIC-III Award, the Corcoran Award and the Mid-Atlantic Section Outstanding Teaching Award from ASEE.

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, N.J., in 2001. She is currently an Associate Professor of electrical and computer engineering at Rowan University. Her research interests include virtual reality, artificial intelligence, and modeling and scheduling of computer-integrated systems. Tang has led or participated in several research and education projects funded by National Science Foundation, U.S. Department of Transportation, U.S. Navy, the Charles A. and Anne Morrow Lindbergh Foundation, the Christian R. and Mary F. Lindback Foundation, and industry firms. Her work has resulted in more than 60 journal and conference papers and book chapters. 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, and the collaboration with community colleges to develop interactive games in empowering students with engineering literacy and problem-solving.

Dr. Sachin Shetty, Tennessee State University

Sachin Shetty received the B.E. degree in computer engineering from Mumbai University, India, in 1998, M.S. in computer science from University of Toledo and Ph.D. in modeling and simulation from Old Dominion University in 2007. He is currently an Assistant Professor in the Electrical and Computer Engineering Department at Tennessee State University. His area of competency includes theoretical and experimental research in network protocols design, security algorithms, and system implementation of cognitive radio networks and wireless sensor networks. He has authored and coauthored more than 30 technical refereed and non-refereed papers in various conferences, international journal articles, and book chapters in research and pedagogical techniques.

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 a faculty member at Bucknell University, where he is currently Professor of electrical engineering. His research interests are in the areas of statistical signal processing, sensor networking, sensor fusion, and communications.

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 has published more than 100 manuscripts in peer-reviewed journals and conferences. He serves on the editorial boards of the Journal of the Franklin Institute and the EURASIP Journal on Wireless Communications and Networking, and he was an Associate Editor for IEEE Signal Processing Letters.

Prof. Robert M. Nickel, Bucknell University

R. M. Nickel received the Diplom-Ing. degree in electrical engineering from the Rheinisch-Westflische Technische Hochschule (RWTH), Aachen, Germany, in 1994 and the M.S. degree in electrical engineering and the Ph.D. degree from the University of Michigan, Ann Arbor, in 1997 and 2001, respectively. During the 2001-02 academic year, he was an adjunct faculty member in the Department of Electrical Engineering and Computer Science, University of Michigan. From 2002 until 2007, he was a faculty member at the Pennsylvania State University, University Park. Since the fall of 2007, he has been a faculty member at the Electrical Engineering Department, Bucknell University, Lewisburg, Penn. His main research interests include speech signal processing and general signal theory.

Dr. Steven H. Chin, Rowan University

Steven Chin is a graduate of Rutgers University, College of Engineering, where he holds a bachelor of science and a doctoral degree in electrical engineering. He received his master of science in electrical engineering from the Johns Hopkins University. His background is in the area of signal/image processing, with application to communication systems. He previously was with the Catholic University of America before joining Rowan University in 1997 as the Associate Dean of engineering. He presently serves as Interim Dean of engineering at Rowan University.

PROJECT BASED DESIGN OF A BIOMETRIC FACE RECOGNITION SYSTEM

ABSTRACT

It is very important that biometrics education, particularly at the undergraduate level, keeps pace with the rapidly growing global market. This paper describes a senior level project in face biometrics that fits in a variety of courses in order to reach out to many students. The project has broad learning outcomes, namely, enhanced application of math skills, improved software implementation skills, enhanced communication skills, increased interest in biometrics, and enhanced ability to carry out open-ended design. Assessment results based on the analysis of the student projects and student surveys related to the learning outcomes show that the project was very successful.

INTRODUCTION

Biometrics is the science of recognizing and authenticating people using their physiological features. Interest in biometrics has increased significantly after the 9/11 attacks. Border and immigration control, restricted access to facilities and information systems, cybersecurity, crime investigations and forensic analysis are just a few of the primary application areas of biometrics used by commercial, government and law enforcement agencies [1]. The biometrics market has grown from $2.7 billion in 2007 to an expectation of $7.1 billion in 2012, with a compound annual growth rate of 21.3 percent [2]. There is much research interest in different biometric systems, notably, face recognition. Face recognition systems have advantages including ease of use and implementation, low cost and high user acceptance [3]. In addition, they can be easily integrated (no special hardware except for a Web camera) with many devices including desktops, laptops, cell phones, wireless access points, iPhones, iPads and PDAs.

There is an acute need for biometrics education at the undergraduate and graduate levels. Many institutions world-wide have an established graduate program in biometrics and offer senior level undergraduate elective courses [4][5] in the area. The University of West Virginia offers a Bachelor of Science in Biometric Systems. The U.S. Naval Academy has a Biometrics Research Laboratory with an aim to enhance undergraduate biometrics education [5] where a senior undergraduate elective course on Biometric Signal Processing is offered that integrates lecture and laboratory experiences. Configuring a new undergraduate program and/or a new biometrics laboratory requires enormous resources that are beyond the reach of most institutions even in the best of economic times. This paper describes one senior level project, which is part of an NSF-sponsored effort to vertically integrate biometrics across an existing undergraduate curriculum. At the senior undergraduate level, the biometrics projects are designed to fit in a variety of courses in order to reach out to many students. The projects are being designed to have broad learning outcomes.

This paper is about a face recognition project focused on open-ended design that is integrated into a senior undergraduate course on biometric systems. In implementing a face recognition system, students go through each step, namely, feature extraction and processing, classification (training and use in rendering a decision) and performance evaluation. The AT&T database is used to show students that robustness to mismatched training and testing conditions is a significant practical issue. The open-ended aspects include researching different robust features, implementing different classifiers and investigating feature and classifier fusion to augment performance. The assessment results are very encouraging with respect to the achievement of the learning outcomes.

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 read papers and apply algorithms (like robust feature extraction) to achieve a better design thereby providing research experience.
- Enhanced communication skills.
- Comprehension of the importance of vertical integration: Students realize that their experiences are part of a flow that contributes to a unified knowledge base.

DESCRIPTION OF PROJECT

The face database is first described. Then, the actual project assignment is discussed. Students are taught the mathematical background and concepts of the discrete cosine transform (DCT) and feature extraction. The basics of neural networks design and the k nearest neighbor (kNN) classifier are also taught along with the decision logic used for face identification. The deliverables for the project are a formal report and well-commented MATLAB code organized in a modular fashion with a brief description on how to run the code.

AT&T Database

The AT&T database is freely downloadable and contains a set of 400 face images. There are ten different images of each of 40 distinct subjects. For some subjects, the images were taken at different times, varying the lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses). All the images were taken against a dark homogeneous background with the subjects in an upright, frontal position (with tolerance for some side movement). The files are in PGM format, and can conveniently be viewed on UNIX (TM) systems using the 'xv' program. They can also be easily read into MATLAB (the programming language used in the project). The size of each image is 112 by 92 pixels, with 256 grey levels per pixel. The images are organized in 40 directories (one for each subject), which have names of the form `sX`, where `X` indicates the subject number (between 1 and 40). In each of these directories, there are ten different images of that subject, which have names of the form `Y.pgm`, where `Y` is the image number for that subject (between 1 and 10).

The various parts of the project assignment are described in the instructional type format that is given to the students. There are six parts to the project.

Project Assignment Part 1: Reading Assignment

Read the tutorial paper [3] and write a critical synopsis on biometrics in general and face recognition in particular. Also, read and develop a general understanding of the system in [6] as the methods in [6] will be implemented.

Project Assignment Part 2: Familiarization with Database

Using the 'imread' and 'imshow' commands in MATLAB, plot the face images of several subjects. Develop an appreciation of the differences in lighting, facial expressions (open / closed eyes, smiling / not smiling) and facial details (glasses / no glasses) of the different images.

Project Assignment Part 3: Two dimensional (2-D) DCT and inverse 2-D DCT

Pick any image from the database. The file for this image will be referred to as face.pgm but you can call it as you deem convenient. Do the following:

1. Read and plot the image.
2. Find the two-dimensional (2-D) DCT of the image.
3. Plot the 2-D DCT.
4. Find the inverse 2-D DCT to recover the original image and plot it.

The MATLAB commands given below will be of use.

```
[img,map]=imread('face.pgm');
imshow(img,map);
img2dct=dct2(img);
imshow(img2dct,map);
imgrecover=idct2(img2dct);
imshow(imgrecover,map);
```

The 2-D DCT plot does not clearly reveal that the DCT coefficients with large magnitudes are concentrated in the upper left-hand corner of the matrix (that is at the low frequencies). Convert the 2-D DCT to its log magnitude so that this concept can be realized using the log magnitude of the DCT. You should get a plot similar to Figure 1(b) in [6]. The equation that converts a DCT C(u,v) to its log magnitude L(u,v) is given by [6]

$$L(u,v) = 255 \frac{\log(1 + 0.01|C(u,v)|)}{\log(1 + 0.01[\max_{u,v}|C(u,v)|])} \tag{1}$$

Project Assignment Part 4: Feature Extraction

Write a MATLAB program that computes the 2-D DCT of an image and scans it in a ‘zigzag’ fashion (see Figure 1) to convert it into a one-dimensional (1-D) DCT feature vector [6]. Add comments to the code to give clear explanations. The left part of Figure 1 illustrates the concept of converting a 2-D array into a 1-D array. The right part of Figure 1 shows how the 2-D array is scanned (‘zigzag’ fashion) to get the 1-D array.

For any image in the database, the 1-D feature vector can be truncated to any length L by retaining only the first L components. Plot the 1-D feature vectors of length 9, 35 and 100 for any image in the database and comment on your results. Do the same for an image from another subject. Do you observe any differences between the DCT vectors of the two subjects?

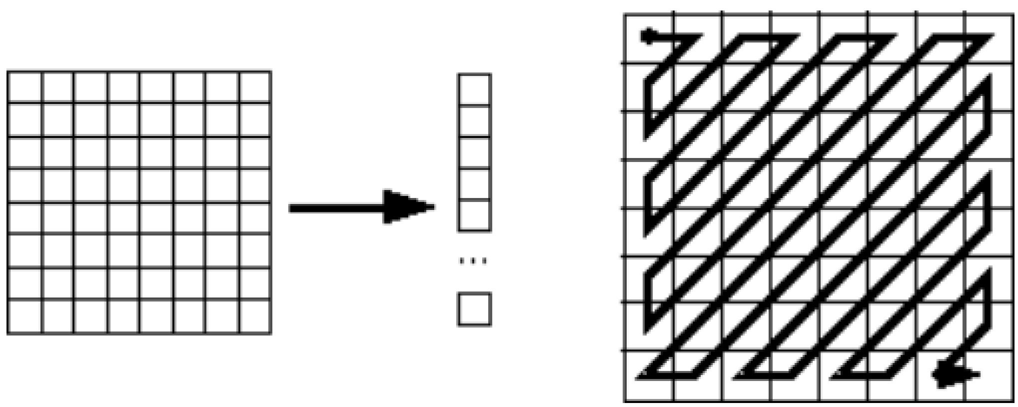

Figure 1. A ‘zigzag’ scanning of a 2-D DCT array to get a 1-D feature vector [6]

Project Assignment Part 5: Face Identification System

A neural network is an example of a supervised classifier in that each training feature vector is accompanied by a class label. Figure 2 shows an example of a three class problem in which the neural network partitions the space into three distinct regions, one for each class. A test feature vector will be classified as belonging to one of the three classes depending on what region it occupies in the space.

Use a neural network to accomplish face identification. Write all the code in MATLAB with detailed comments. Note that the number of classes is equal to the number of subjects. Use a multilayer perceptron (MLP) with one hidden layer [7]. For each subject, use the first five files (1.pgm to 5.pgm) for training the network. Use the files 6.pgm to 10.pgm for the performance evaluation. The identification success rate is the number of face images identified correctly divided by the total number of face images tested.

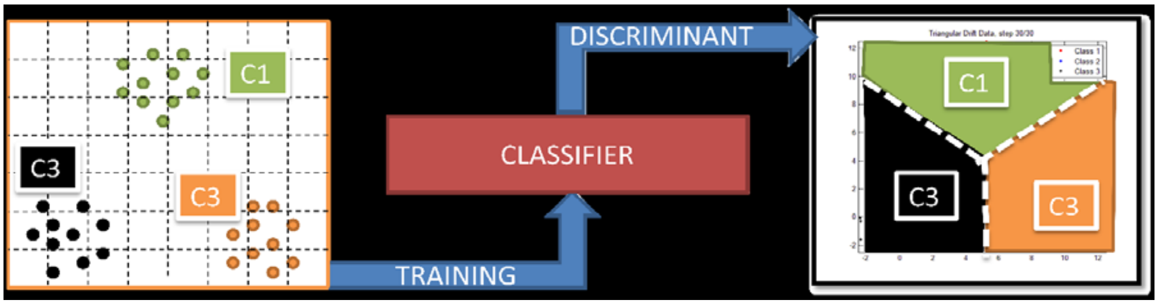

Figure 2. A supervised classifier

Note that for training and testing, there will be one DCT vector for each image. For training and testing the neural network, implement the scaling procedure on the DCT vector as in Section 3.2 of [6]. For the scaling procedure, suppose there are p training feature vectors (one for each image) given by $x^{(j)} = [x(1)^{(j)}\ x(2)^{(j)} \ldots x(n)^{(j)}]$ for j = 1 to p where n is the dimension of the feature vector. The training vector $x^{(j)}$ is scaled to $z^{(j)}$ by the use of Equations (2), (3) and (4) as given below [6].

$$b(i) = \beta \max[1, x(i)^{(1)}, x(i)^{(2)}, \ldots, x(i)^{(p)}] \tag{2}$$

$$a(i) = \beta \min[-1, x(i)^{(1)}, x(i)^{(2)}, \ldots, x(i)^{(p)}] \tag{3}$$

$$z(i)^{(j)} = \frac{2[x(i)^{(j)} - a(i)]}{b(i) - a(i)} \tag{4}$$

For Equations (2), (3) and (4), $\beta = 1.1$ and i = 1 to n. The scaled feature vectors $z^{(j)}$ are used to train the MLP. During testing, the test feature vectors are also scaled as above prior to classification with the values of a(i) and b(i) calculated from the training data.

Train and do the performance evaluation using an MLP with one hidden layer. For each experiment, perform 10 random runs to get an average identification success rate. Investigate the identification success rate as a function of:

- The number of subjects (from 10 to 40).
- The number of hidden layer nodes (from 25 to 100).
- Dimension of the 1-D DCT feature vector (from 10 to 100).

Project Assignment Part 6: Open-Ended Component

Although students were free to explore their own ideas for open-ended design with the aim of augmenting the identification success rate, some suggestions were made as given below:

- Research other features.
- Use other classifiers like k Nearest Neighbor, Support Vector Machines and Gaussian Mixture Models.
- Perform classifier fusion.
- For a given classifier, examine feature fusion strategies. Examples are decision level fusion, probability level fusion and Borda count [8]. Combine feature and classifier fusion.

ASSESSMENT RESULTS

For the open-ended design, most students implemented either the k Nearest Neighbor or the Support Vector Machine classifier and did a comparison with the MLP classifier. It was surprising that no student attempted fusion. Table 1 gives the results of a survey given to 18 students. The survey questions are related to the learning outcomes. For each statement in Table 1, students are asked to respond with a score of 1, 2, 3, 4 or 5 where:

- 1 – Strongly disagree, 2 – Disagree, 3 – Neutral. 4 – Agree and 5 – Strongly Agree.

Statement	Mean	Median	Standard Deviation
The project helped reinforce MATLAB software skills.	4.44	5.00	0.70
The project helped reinforce written communication skills.	4.22	4.00	0.65
The project enriched mathematical and analytical skills.	4.28	4.00	0.46
The project helped gain an appreciation of how pattern recognition works.	4.11	4.00	0.58
The project helped gain an appreciation of the field of biometrics.	4.00	4.00	0.59
The project helped gain valuable experience in open-ended design of face biometric systems.	4.11	4.00	0.32

Table 1. Results of survey related to learning outcomes

Student perception of vertical integration was assessed by giving them a list of sophomore and junior/senior courses and asking them whether the material learned in these courses had a connection with the face recognition project. The sophomore courses included Basic Circuits, Electronics, Digital Circuits and Mathematics (differential equations, linear algebra, complex variables and probability and statistics). The junior/senior level courses included Digital Signal Processing, Communications, Advanced Electronics, Control Systems, Microprocessors and Computer Architecture. Seventeen out of eighteen students selected Digital Signal Processing, eight picked Mathematics and seven students picked Control Systems.

SUMMARY AND CONCLUSIONS

The biometric face identification project has achieved many learning outcomes, given the students a perception of the usefulness of vertical integration and stimulated interest in biometrics. Students implemented a complete system, did a performance evaluation and understood one of the main problems in biometrics research, namely the lack of robustness due to mismatched training and testing conditions. Surveys conducted after the project revealed that the students perceived the project as successful in meeting the desired learning outcomes.

ACKNOWLEDGEMENT

This work was supported by the National Science Foundation through TUES Type 2 Collaborative Research Grants DUE-1122296, DUE-1122344 and DUE-1122299.

REFERENCES

1. A. K. Jain, P. Flynn and A. A. Ross, Handbook of Biometrics, Springer, 2008.
2. The Global Biometrics Market, BCC Research, January 2007. (http://www.sbwire.com/news/view/18766).
3. A. K. Jain, A. Ross and S. Prabhakar, "An introduction to biometric recognition", IEEE Transactions on Circuits and Systems for Video Technology, Vol. 14, No. 1, January 2004.
4. S. Cotter, "Laboratory Exercises for an Undergraduate Biometric Signal Processing Course", ASEE Annual Conference, Louisville, Kentucky, June 2010.
5. R. W. Ives, Y. Du, D. M. Etter and T. B. Welch, "A Multidisciplinary Approach to Biometrics", IEEE Transactions on Education, Vol. 48, No. 3, pp. 462–471, August 2005.

6. Z. Pan and H. Bolouri, "High Speed Face Recognition Based on Discrete Cosine Transforms and Neural Networks", 1999.

7. S. Haykin, Neural Networks: A Comprehensive Foundation, Prentice-Hall, 1999.

8. R. Polikar, “Ensemble Based Systems in Decision Making”, IEEE Circuits and Systems Magazine, Vol. 6, No. 3, pp. 21–45, 2006.