BIOMETRIC SIGNAL PROCESSING LABORATORY

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ABSTRACT

Biometric systems verify a person's identity based on unique physical attributes. Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions. It is a broad subject, which integrates image processing, digital signal processing, statistics, mathematics, computing, psychology and legislation. To enable the average undergraduate to understand and internalize the biometric theories and technologies, we have developed a biometric signal processing laboratory at the U.S. Naval Academy. This paper describes the model of the lab, introduces the key biometric equipment, and overviews our lab activities.

1. INTRODUCTION

Biometrics is an emerging field of technology using unique and measurable physical, biological, or behavioral characteristics that can be processed electronically to establish identification, and to perform identity verification or automated recognition of a person[1]. These physical attributes include facial appearance, fingerprints, hand geometry, handwriting, iris, retina, veins, and voice. For example, fingerprint recognition uses a fingerprint impression that is analyzed for ridge ends, bifurcation, or dots; voice recognition uses a speech signal that is analyzed to determine characteristics of a person's voice; iris recognition uses an image of the iris that is mapped to a digital image for processing; and face recognition uses a video image of a face that is processed to yield facial parameters[1]. Compared to the traditional identification/verification methods, such as paper or plastic IDs, biometrics can be more convenient for users, has lower costs for business, reduces fraud, and is more secure. Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions. The need for biometrics can be found in federal, state and local governments, in the military, and in commercial applications.

As a broad subject, biometrics integrates image processing, digital signal processing, statistics, mathematics, computing, psychology, and legislation. To introduce our students to this important set of topics, the Electrical Engineering Department at the U.S. Naval Academy has developed a biometric signal processing laboratory. This paper describes the model of our biometric laboratory, introduces the key biometric equipment, and overviews our lab activities.

2. BIOMETRIC LAB EQUIPMENT

Figure 1 shows the model of the biometric lab, which includes the following biometric systems: five iris recognition systems, four fingerprint recognition systems, four voice recognition systems, one 2D face recognition system, one 3D face recognition system, three video camera systems for real-time motion detection and one server for the biometric database management. These commercial systems are used to provide the students a familiarity with state-of-the-art biometric identification equipment.

Instead of combination locks, biometric systems are used for entrance access control to the lab. The door can be connected to a face recognition system (the Acsys Veraport System), or an iris recognition system (the LG IrisAccess System). In addition, the lab contains three video cameras (including a Canon VC-C4 Pan/Tilt/Zoom camera) that are mounted at three locations on the ceiling. Fingerprint (the SecuGen ® Hamster), voice recognition (which includes the Dragon NaturallySpeaking's software, the Sound Professionals SP-CMC-4 microphone and the Creative Lab Sound Blaster® Extigy external soundcard), and iris recognition systems (the Panasonic Authenticam & PrivateID system) are connected to all workstations, and the fingerprint identification is used to replace traditional username-password access control. In addition, a 3D face recognition system (the A4 Vision 3D face recognition system) is installed on one workstation. The iris scan enrollment system is installed on the server. MATLAB has been installed on all the computers and the server to allow algorithm development.

2.1 Fingerprint Recognition System

The practice of using fingerprints as a means of identification is an indispensable aid to modern law enforcement. Every person has minute raised ridges of skin on the inside surfaces of their fingers, which display a number of characteristics known as minutiae (Fig. 2). The minutiae do not change naturally during a person's life. Through the history of fingerprinting, no two fingerprints have ever been found to match exactly [2]. Fingerprint recognition systems usually include a sensor to take fingerprints and software for fingerprint analysis and recognition. SecuGen® Hamster III is an optical sensor using patented SEIR fingerprint biometric technology. It is easy to use and can be installed quickly on any Windows PC.

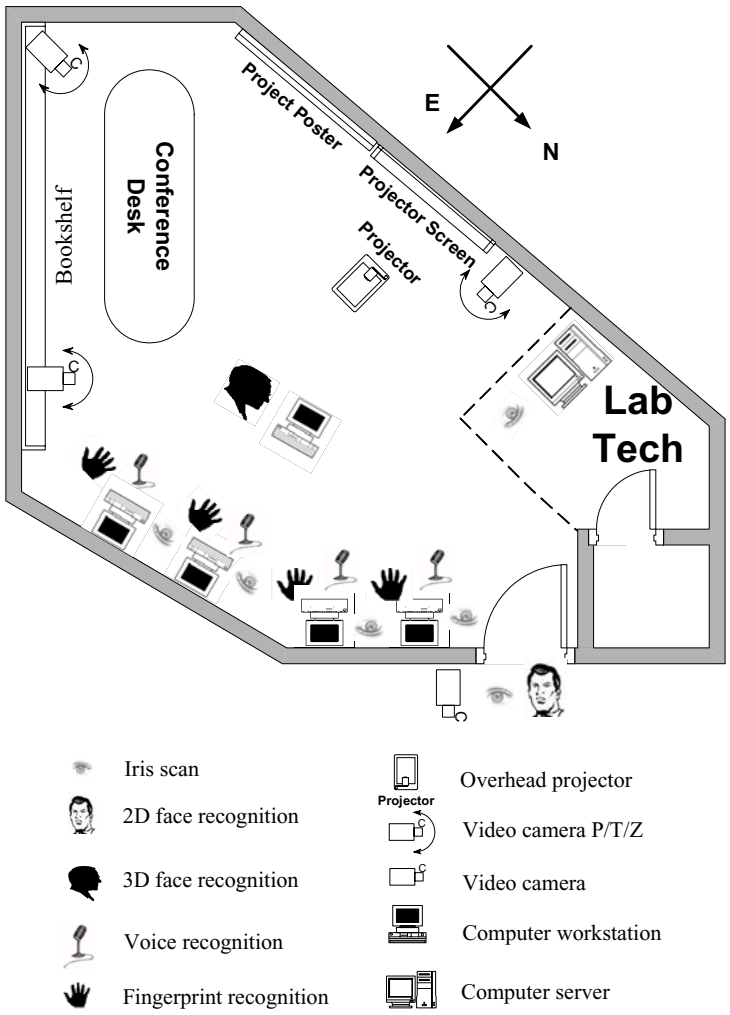


Fig. 1. The model of the biometric lab.

(a) (b)

Fig. 2. Fingerprint Recognition: (a) Digitized Fingerprint, (b) Fingerprint in Detail.

2.2 Voice Recognition Systems

Speech is produced as a sequence of sounds. The state of the vocal cords, as well as the positions, shapes, and sizes of the various articulators, changes over time to reflect the sound being produced (Fig. 3)[3]. The vowel sounds are perhaps the most interesting class of sounds in English. Their importance to the classification and representation systems rely heavily on vowel recognition to achieve high performance[1,3]. The voice recognition can be used in conjunction with other biometric system(s) to create a more robust recognition system[4]. The voice recognition accuracy rate (for English) of the Dragon Naturally Speaking's software can be as high as 99% for well trained users and 60~70% for the novice user[5]. The Sound Professionals SP-CMC-4 microphone has a frequency response of 30Hz to 20,000 Hz. The output is low impedance balanced (200 ohms). The Creative Lab Sound Blaster® Extigy external sound card provides 24-bit audio with easy USB connection.

2.3 Iris Recognition Systems

Iris recognition combines computer vision, pattern recognition, statistics, and the human-machine interface. Because the iris is a protected internal organ whose random texture is stable throughout life[6], it can serve as a living passport or a living password that one need not remember but always carries along (Fig. 4). The iris recognition principle is a test of statistical independence using multi-scale quadrature wavelets[7]. Because the randomness of iris patterns has very high dimensionality, recognition decisions are made with confidence levels high enough to support rapid and reliable exhaustive searches through national-sized databases. Two kinds of iris recognition systems are used: the Panasonic Authenticam &

PrivateID system (installed with the PCs) and the LG IrisAccess System (for door access control).

The Panasonic Authenticam & PrivateID system includes Panasonic Authenticam (for taking iris patterns) and the bounded PrivateID software (for iris recognition). In this system, the enrollment, identification and database are integrated together. However, the LG Iris Access System is more complex and provides a higher level of security. The LG Iris Access System includes a Enrollment Optical Unit (EOU) (connected with the server for iris enrollment), a Remote Optical Unit (ROU 3000) (installed at the eastern door for iris scan), an Identification Control Unit (ICU 3000) (installed on the wall inside the lab for iris idenfication), a Frame Grabber Board (FGB 3000) (installed in the server for iris pattern digitization), a Door Interface Board (DIB 3000) (installed in the server for door control), and a server pc (i.e. the server).

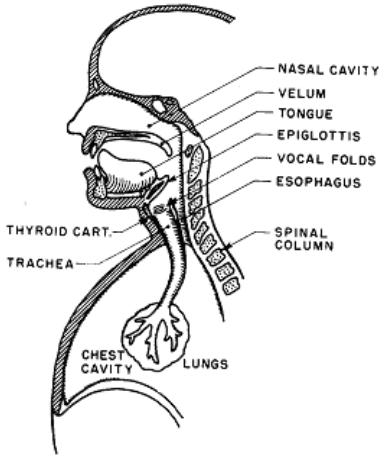


Fig. 3. Schematic view of the human vocal mechanism

2.4 2D Face Recognition System (the Acsys Veraport System)

Face recognition has become one of the major areas of biometric research because of its non-invasive nature and because it is a person's primary method of personal identification. The fundamental principle of face recognition (Fig. 5) is to use a special mathematical model to measure the dissimilarity of features in the face[2]. The Acsys Veraport System face tracking and recognition technology to provide non-intrusive biometric access control. The system uses a client-server architecture for ease of use and fault-tolerant reliability. It provides remote video monitoring, annunciation, video/audio recording and remote manual intervention.

(a) (b)

Fig. 4. Iris Recognition: (a) Digitized Iris, (b) Iris Code

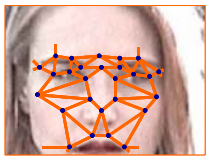


Fig. 5. Face Recognition (Face with Feature Extraction)

(a) (b)

Fig. 6. 3D Face Recognition: (a) The structured lighting pattern distorted by the face's surface features, (b) The reconstructed 3D surface and texture.

2.5 3D Face Recognition System (A4 Vision System)

The 3D face recognition applies 3D face models to the problem of robust face recognition. In particular, the 3D face models address the two most critical and complicating factors affecting 2D face recognition performance: illumination and pose variation[8]. In the A4 Vision system, the structured light is used to acquire the 3D geometry of the face (Fig. 6(a)). The 3D reconstruction algorithms are used to formulate the 3D surface and the texture of the face (Fig. 6(b)).

3. OVERVIEW OF BIOMETRIC LAB ACTIVITIES

The biometric lab provides the following activities in conjunction with our biometric signal processing course:

- Field trips

  A one-day field trip was organized to the biometric consortium conference (September 2003, Crystal City, VA), which included a plenary speech, research presentations, and exhibits. This field trip allowed students to have an introduction to biometrics and motivated their interest for future biometric study. More field trips, such as field trips to biometric research labs, vendors and conferences, were organized during the biometric course.

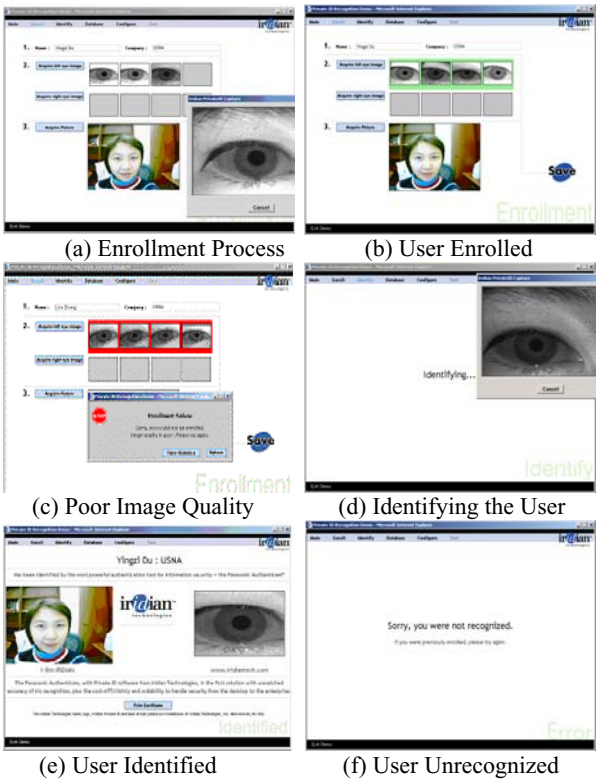
- Biometric seminar series

  Experts are invited to give guest lectures about biometric science, technologies, and policies. These seminars are open to students and faculty members.

- Interactive demos

  Demonstrations of fundamental topics are necessary additions to the theory. Moreover, the demonstrations teach the students the procedures of biometric data collection, integrity of process, and safety tips. One such demonstration is described in the following.

Fig. 7 illustrates the iris enrollment and identification process. Fig. 7(a) displays the computer screen while in the process of enrollment. The system requires four iris images of the same eye for enrollment. The system also takes a picture of the user. If all four iris images are of good quality, the system will allow the user to enroll (Fig. 7(b)), otherwise, it will reject the enrollment and give the warning as shown in Fig. 7(c) and the user must enroll again. After enrollment, the system can identify the user via his/her registered iris (Fig. 7(e)). However, for the same user, the unregistered iris (i.e. the other eye) could not be used to access the system. In this demo (Fig. 7(f)), the user used her left eye for enrollment and used her right eye for identification. The system could not recognize the user. From this simple demonstration, students learn the concepts of iris recognition, enrollment and verification/identification. This example also demonstrated the process of iris recognition, the importance of image quality and user co-operation for iris recognition, and the uniqueness of the human iris.



(a) Enrollment Process (b) User Enrolled

(c) Poor Image Quality (d) Identifying the User

(e) User Identified (f) User Unrecognized

Fig. 7. Iris Recognition Demo

- Lab exercises

  Students utilize the state-of-the-art biometric technologies. With MATLAB, students can implement and test the biometric algorithms using image processing techniques.

- Undergraduate research

  Currently, we have several areas of biometric research. These projects include: (1) investigate the vulnerabilities of commercial biometric systems to help in developing more secure biometric systems; (2) develop functional components for "smart rooms"; and (3) take advantage of multiple low-cost sensors for use in the construction of a high-resolution image from multiple low-resolution images. Senior students can participate in any one of these research projects. They contribute to the success of the projects here at USNA and bring their experience and expertise to follow-on jobs with the Navy or Marine Corps. Some of our students also have the opportunity to continue into graduate studies.

- Other activities

  Additionally, we are building a biometric library and establishing an electronic biometric database to support biometric classes and researches.

4. CONCLUSIONS

We have developed a biometric laboratory to support an undergraduate course in biometric signal processing and research. The biometric lab uses iris scan and face recognition systems for entrance control. Within the lab, the following biometric systems have been installed: five iris recognition systems, four fingerprint recognition systems, four voice recognition systems, one face recognition system, one 3D face recognition system, three video camera systems, and a server to manage the biometric database and iris enrollment. Our lab provides following activities: field trips, biometric seminar series, interactive demos, lab exercises, and undergraduate research. Through the lab activities, students can explore biometric sciences, technologies and applications. In the future we will expand the biometric lab, pursue more research projects, and develop custom software/programs for undergraduate courses and research[9].

5. ACKNOWLEDGEMENTS

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