

ANALYSIS OF BIOMETRIC MULTIMODAL BIOMETRICS MECHANISM

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ABSTRACT

Biometric recognition refers to an automatic recognition of individuals based on a feature vector(s) derived from their physiological and/or behavioural characteristic. Biometric recognition systems should provide a reliable personal recognition schemes to either confirm or determine the identity of an individual. Applications of such a system include computer systems security, secure electronic banking, mobile phones, credit cards, secure access to buildings, health and social services. By using biometrics a person could be identified based on "who she/he is" rather than "what she/he has" (card, token, key) or "what she/he knows" (password, PIN). In this paper, a brief overview of biometric methods, both unimodal and multimodal, and their advantages and disadvantages, will be presented.

Keywords: Biometrics, Multimodal Biometrics, Recognition, Verification, Identification, Security.

1. INTRODUCTION

The term biometric comes from the Greek words bios (life) and metrikos (measure). It is well known that humans intuitively use some body characteristics such as face, gait or voice to recognize each other. Since, today, a wide variety of applications require reliable verification schemes to confirm the identity of an individual, recognizing humans based on their body characteristics became more and more interesting in emerging technology applications. Traditionally, passwords and ID cards have been used to restrict access to secure systems but these methods can easily be breached and are unreliable. Biometric cannot be borrowed, stolen, or forgotten, and forging one is practically impossible.

2. BIOMETRIC SYSTEMS

A biometric system is essentially a pattern-recognition system that recognizes a person based on a feature vector derived from a specific physiological or behavioral characteristic that the person possesses [1]. That feature vector is usually stored in a database (or recorded on a smart card given to the individual) after being extracted. A biometric system based on a physiological characteristics is generally more reliable than one which adopts behavioural characteristics, even if the latter may be more easy to integrate within certain specific applications. Biometric system can than operate in two modes: verification or identification. While identification involves comparing the acquired biometric information against templates corresponding to all users in the database, verification involves comparison with only those templates corresponding to the claimed identity. This implies that identification and verification are two problems that should be dealt with separately.

A simple biometric system consists of four basic components:

- 1) Sensor module which acquires the biometric data;
- 2) Feature extraction module where the acquired data is processed to extract feature vectors;
- 3) Matching module where feature vectors are compared against those in the template;
- 4) Decision-making module in which the user's identity is established or a claimed identity is accepted or rejected.

Any human physiological or behavioural trait can serve as a biometric characteristic as long as it satisfies the following requirements:

- 1) Universality. Everyone should have it;
- 2) Distinctiveness. No two should be the same;
- 3) Permanence. It should be invariant over a given period of time;
- 4) Collectability.

In real life applications, three additional factors should also be considered: performance (accuracy, speed, resource requirements), acceptability (it must be harmless to users), and circumvention (it should be robust enough to various fraudulent methods).

3. OVERVIEW OF COMMONLY USED BIOMETRICS

Since there are number of biometric methods in use (some commercial, some "not yet"), a brief overview of various biometric characteristics will be given, starting with newer technologies and then progressing to older ones [2]:

Gait. This is one of the newer technologies and is yet to be researched in more detail. Basically, gait is the peculiar way one walks and it is a complex spatio-temporal biometrics. It is not supposed to be very distinctive but can be used in some low-security applications. Gait is a behavioural biometric and may not remain the same over a long period of time, due to change in body weight or serious brain damage. Acquisition of gait is similar to acquiring a facial picture and may be an acceptable biometric. Since video-sequence is used to measure several different movements this method is computationally expensive.

Keystroke. It is believed that each person types on a keyboard in a characteristic way. This is also not very distinctive but it offers sufficient discriminatory information to permit identity verification. Keystroke dynamics is a behavioral biometric; for some individuals, one could expect to observe large variations in typical typing patterns. Advantage of this method is that keystrokes of a person using a system could be monitored unobtrusively as that person is keying information. Another issue to think about here is privacy.

Hand geometry. The essence of hand geometry is the comparative dimensions of fingers and the location of joints, shape and size of palm. One of the earliest automated biometric systems was installed during late 60s and it used hand geometry and stayed in production for almost 20 years. The technique is very simple, relatively easy to use and inexpensive. Dry weather or individual anomalies such as dry skin do not appear to have any negative effects on the verification accuracy. Since hand geometry is not very distinctive it cannot be used for identification of an individual from a large population, but rather in a verification mode. Further, hand geometry information may not be invariant during the growth period of children. Limitations in dexterity (arthritis) or even jewelry may influence extracting the correct hand geometry information. This method can find its commercial use in laptops rather easy. There are even verification systems available that are based on measurements of only a few fingers instead of the entire hand. These devices are smaller than those used for hand geometry.

Fingerprint. A fingerprint is a pattern of ridges and furrows located on the tip of each finger. Fingerprints were used for personal identification for many centuries and the matching accuracy was very high [3]. Patterns have been extracted by creating an inked impression of the fingertip on paper. Today, compact sensors provide digital images of these patterns. Fingerprint recognition for identification acquires the initial image through live scan of the finger by direct contact with a reader device that can also check for validating attributes such as temperature and pulse. Since the finger actually touches the scanning device, the surface can become oily and cloudy after repeated use and reduce the sensitivity and reliability of optical scanners. Solid state sensors overcome this and other technical difficulties because the coated silicon chip itself is the sensor. Solid state devices use electrical capacitance to sense the ridges of the fingerprint and create a compact digital image. Today, a fingerprint scanner costs about 20 USD and has become affordable in a large number of applications (laptop computer). In real-time verification systems, images acquired by sensors are used by the feature extraction module to compute the feature values. The feature values typically correspond to the position and orientation of certain critical points known as minutiae points [4]. The matching process involves comparing the two-dimensional minutiae patterns extracted from the user's print with those in the template. One problem with the current fingerprint recognition systems is that they require a large amount of computational resources.

Face. Facial recognition [14] analyzes the characteristics of a person's face images input through a digital video camera. It measures the overall facial structure, including distances between eyes, nose, mouth, and jaw edges. These measurements are retained in a database and used as a comparison when a user stands before the camera. This biometric has been widely, and perhaps wildly, touted as a fantastic system for recognizing potential threats (whether terrorist, scam artist, or known criminal) but so far has been unproven in high-level usage. Facial recognition can be used for both identification and verification purposes.

User faces the camera, standing about two feet from it. The system will locate the user's face and perform matches against the claimed identity or the facial database. It is possible that the user may need to move and reattempt the verification based on his facial position. The system usually comes to a decision in less than 5 seconds. To prevent a fake face or mold from faking out the system, many systems now require the user to smile, blink, or otherwise move in a way that is human before verifying.

Retina. Retina recognition [15] technology captures and analyzes the patterns of blood vessels on the thin nerve on the back of the eyeball that processes light entering through the pupil. Retinal patterns are highly distinctive traits. Every eye has its own totally unique pattern of blood vessels; even the eyes of identical twins are distinct. Although

each pattern normally remains stable over a person's lifetime, it can be affected by disease such as glaucoma, diabetes, high blood pressure, and autoimmune deficiency syndrome.

The fact that the retina is small, internal, and difficult to measure makes capturing its image more difficult than most biometric technologies. An individual must position the eye very close to the lens of the retina-scan device, gaze directly into the lens, and remain perfectly still while focusing on a revolving light while a small camera scans the retina through the pupil. Any movement can interfere with the process and can require restarting. Enrolment can easily take more than a minute.

Iris. Iris recognition [13] is another developed biometric recognition system capable of positively recognizing the identity of individuals without physical contact. The iris is the colored portion of the eye that surrounds the pupil. The boundary of the pupil is defined by the video capture device, eyelid occlusion and specular reflection discounted, and the quality of the image is determined for processing. Iris patterns are processed and encoded, which are stored and used for future recognition transactions. Iris recognition usually takes only a second or two to complete and can accommodate both eyeglass and contact wearers. Iridian Technologies, Inc. of Moorestown, NJ leads the world in research, development and marketing of authentication technologies based on iris recognition -- the most accurate biometric identifier.

Iris scanning is one of the most accurate biometric user authentication techniques. High accuracy results from the fact that iris is very distinctive and rarely changes. The drawback is that the hardware employed is large and expensive. It requires user-training and controlled lighting.

Voice. The features of an individual's voice are based on physical characteristics such as vocal tracts, mouth, nasal cavities and lips that are used in creating a sound. These characteristics of human speech are invariant for an individual, but the behavioral part changes over time due to age, medical conditions and emotional state. Voice recognition techniques are generally categorized according to two approaches: 1) Automatic Speaker Verification (ASV) and 2) Automatic Speaker Identification (ASI). Speaker verification uses voice as the authenticating attribute in a two-factor scenario. Speaker identification attempts to use voice to identify who an individual actually is. Voice recognition distinguishes an individual by matching particular voice traits against templates stored in a database. Voice systems must be trained to the individual's voice at enrollment time, and more than one enrollment session is often necessary. Feature extraction typically measures formants or sound characteristics unique to each person's vocal tract. The pattern matching algorithms used in voice recognition are similar to those used in face recognition.

Signature. Signature is a simple, concrete expression of the unique variations in human hand geometry. The way a person signs his or her name is known to be characteristic of that individual. Collecting samples for this biometric includes subject cooperation and requires the writing instrument. Signatures are a behavioural biometric that change over a period of time and are influenced by physical and emotional conditions of a subject. In addition to the general shape of the signed name, a signature recognition system can also measure pressure and velocity of the point of the stylus across the sensor pad.

DNA. Deoxyribonucleic acid (DNA) is probably the most reliable biometrics. It is in fact a one-dimensional code unique for each person. Exception is identical twins. This method, however, has some drawbacks: 1) contamination and sensitivity, since it is easy to steal a piece of DNA from an individual and use it for an ulterior purpose, 2) no real-time application is possible because DNA matching requires complex chemical methods involving expert's skills, 3) privacy issues since DNA sample taken from an individual is likely to show susceptibility of a person to some diseases. All this limits the use of DNA matching to forensic applications.

It is obvious that no single biometric is the "ultimate" recognition tool and the choice depends on the application. A brief comparison of the above techniques based on seven factors described in section 2 is provided in Table I [2].

Table I Comparison of various biometric technologies [2]

Biometric characteristic	Universality	Distinctiveness	Permanence	Collectability	Performance	Acceptability	Circumvention
Facial thermogram	H	H	L	H	M	H	L
Hand vein	M	M	M	M	M	M	L
Gait	M	L	L	H	L	H	M
Keystroke	L	L	L	M	L	M	M
Odor	H	H	H	L	L	M	L
Ear	M	M	H	M	M	H	M
Hand geometry	M	M	M	H	M	M	M
Fingerprint	M	H	H	M	H	M	M
Face	H	L	M	H	L	H	H
Retina	H	H	M	L	H	L	L
Iris	H	H	H	M	H	L	L
Palmprint	M	H	H	M	H	M	M
Voice	M	L	L	M	L	H	H
Signature	L	L	L	H	L	H	H
DNA	H	H	H	L	H	L	L

4. BIOMETRIC SYSTEM PERFORMANCE

Due to different positioning on the acquiring sensor, imperfect imaging conditions, environmental changes, deformations, noise and bad user's interaction with the sensor, it is impossible that two samples of the same biometric characteristic, acquired in different sessions, exactly coincide. For this reason a biometric matching systems' response is typically a matching score s (normally a single number) that quantifies the similarity between the input and the database template representations. The higher the score, the more certain the system is that the two samples coincide [1]. A similarity score s is compared with an acceptance threshold t and if s is greater than or equal to t compared samples belong to a same person. Pairs of biometric samples generating scores lower than t belong to a different person. The distribution of scores generated from pairs of samples from different persons is called an impostor distribution, and the score distribution generated from pairs of samples of the same person is called a genuine distribution, Figure 1 [1].

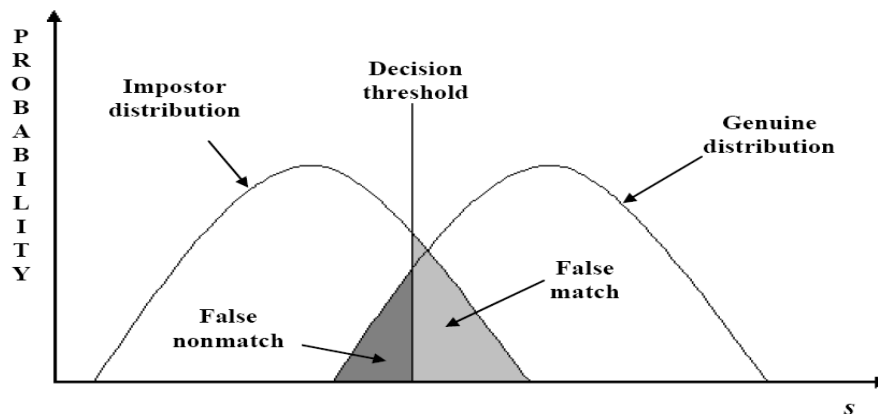


Fig. 1. Biometric system error rates [1]

The main system errors are usually measured in terms of:

- FNMR (false nonmatch rate) – mistaking two biometrics measurements from the same person to be from two different persons;
- FMR (false match rate) – mistaking biometric measurement from two different persons to be from the same person.

FNMR and FMR are basically functions of the system threshold t : if the system's designers decrease t to make the system more tolerant to input variations and noise, FMR increases. On the other hand, if they raise t to make the system more secure, FNMR increases accordingly [1]. FMR and FNMR are brought together in a receiver operating characteristic (ROC) curve that plots the FMR against FNMR (or 1-FNMR) at different thresholds, Figure 2 [1].

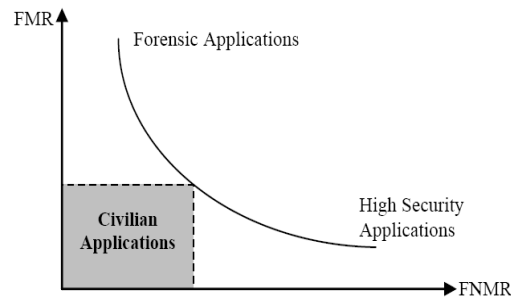


Fig. 2. Receiver operating characteristic (ROC) [1]

There are two other recognition error rates that can be also used and they are: failure to capture (FTC) and failure to enroll (FTE). FTC denotes the percentage of times the biometric device fails to automatically capture a sample when presented with a biometric characteristic. This usually happens when system deals with a signal of insufficient quality. The FTE ratedenotes the percentage of times users cannot enroll in the recognition system.

5. UNIMODAL BIOMETRIC SYSTEMS

There is a variety of problems with biometric systems installed in real world applications which prove that biometrics is not fully solved problem. As shown in Table II [8] there is still plenty of scope for improvement.

Table II State-of-the-Art Error Rates associated with fingerprints, face, and voice biometric systems [8]

Biometric characteristic	Test	Test Parameter	FNMR	FMR
Fingerprint	FVC2002 [3]	Users mostly in the age group 20-39	0.2 %	0.2 %
Face	FRVT2002 [5]	Enrollment and test images were collected in indoor environment and could be on different days	10 %	1 %
Voice	NIST2000	Text dependent	10-20 %	2-5 %

Limitations of biometric systems using any single biometric characteristic [2]:

- 1) Noise in sensed data: Example is a fingerprint with a scare. Noisy data can also result from accumulation of dirt on a sensor or from ambient conditions.
- 2) Intra-class variations: Biometric data acquired from an individual during authentication may be very different from the data that was used to generate the template during enrollment. This variation is typically caused by a user who is incorrectly interacting with the sensor.
- 3) Distinctiveness: While a biometric trait is expected to vary significantly across individuals, there may be large inter-class similarities in the feature sets used to represent these traits. This limitation restricts the discriminability provided by the biometric trait.
- 4) Non-universality: While every user is expected to possess the biometric trait being acquired, in reality it is possible that a group of users do not posses that particular biometric characteristic.
- 5) Spoof attacks: An individual may attempt to forge the biometric trait. This is particularly easy when signature and voice are used as an identifier.

6. MULTIMODAL BIOMETRIC SYSTEMS

Limitations of unimodal biometric systems can be overcome by using multimodal biometric systems [9]. A multimodal biometric system uses multiple applications to capture different types of biometrics. This allows the integration of two or more types of biometric recognition and verification systems in order to meet stringent performance requirements. Such systems are expected to be more reliable due to the presence of multiple, independent pieces of evidence [10]. These systems are also able to meet the strict performance requirements imposed by various applications [11].

A multimodal system could be, for instance, a combination of fingerprint verification, face recognition, voice verification and smart-card or any other combination of biometrics. This enhanced structure takes advantage of the proficiency of each individual biometric and can be used to overcome some of the limitations of a single biometric.

For instance, it is estimated that 5% of the population does not have legible fingerprints, a voice could be altered by a cold and face recognition systems are susceptible to changes in ambient light and the pose of the subject's head. A multimodal system, which combines the conclusions made by a number of unrelated biometrics indicators, can overcome many of these restrictions.

Multimodal biometric systems can be designed to operate in five integration scenarios: 1) multiple sensors, 2) multiple biometrics, 3) multiple units of the same biometric, 4) multiple snapshots of the same biometric, 5) multiple representations and matching algorithms for the same biometric [2].

7. CONCLUSION

Biometrics refers to an automatic recognition of a person based on her behavioural and/or physiological characteristics. Many business applications (e.g. banking) will in future rely on biometrics since using biometrics is the only way to guarantee the presence of the owner when a transaction is made. For instance, fingerprint-based systems have been proven to be very effective in protecting information and resources in a large area of applications. Although companies are using biometrics for authentication in a variety of situations, the industry is still evolving and emerging. At present, the amount of applications employing biometric systems is quite limited, mainly because of the crucial cost-benefit question: supposing biometrics do bring an increase in security, will it be worth the financial cost? The future probably belongs to multimodal biometric systems as they alleviate a few of the problems observed in unimodal biometric systems. Multimodal biometric systems can integrate information at various levels, the most popular one being fusion at the matching score level. Besides improving matching performance, they also address the problem of nonuniversality and spoofing. Finally, the use of biometrics raises several privacy questions. A sound trade-off between security and privacy may be necessary; but we can only enforce collective accountability and acceptability standards through common legislation [1]. For example, if and when facerecognition technology improves to the point where surveillance cameras can routinely recognize individuals, privacy, as it has existed in the public sphere, will be wiped out. Even today, in some major cities, you are recorded approximately 60 times during the day by various surveillance cameras. In spite of all this it is certain that biometric-based recognition will have a great influence on the way we conduct our daily business in near future.

This study is carried out by the authors as we are working on a framework for biometrics security.

8. REFERENCES

- [1] S. Prabhakar, S. Pankanti, A. K. Jain, "Biometric Recognition: Security and Privacy Concerns", IEEE Security & Privacy, March/April 2003, pp. 33-42
- [2] A. K. Jain, A. Ross, S. Prabhakar, "An Introduction to Biometric Recognition", IEEE Trans. on Circuits and Systems for Video Technology, Vol. 14, No. 1, pp 4-19, January 2004
- [3] D. Maio, D. Maltoni, R. Cappelli, J. L. Wayman, A. K. Jain, "FVC2002: Fingerprint verification competition" in Proc. Int. Conf. Pattern Recognition (ICPR), Quebec City, QC, Canada, August 2002, pp. 744-747
- [4] M. Golfarelli, D. Maio, D. Maltoni, "On the error-reject trade off in biometric verification systems," IEEE Trans. Pattern Anal. Machine Intell., Vol. 19, pp. 786-796, July 1997
- [5] J. Daugman, "How Iris Recognition Works", IEEE Trans. on Circuits and Systems for Video Technology, Vol. 14, No. 1, pp. 21-30, January 2004
- [6] L. O'Gorman, "Seven issues with human authentication technologies," in Proc. Workshop Automatic Identification Advanced Technologies (AutoID), Tarrytown, NY, Mar. 2002, pp. 185-186
- [7] L. Hong, A. K. Jain, S. Pankanti, "Can multibiometrics improve performance?," in Proc. AutoID'99, Summit, NJ, October 1999, pp. 59-64
- [8] L. I. Kuncheva, C. J. Whitaker, C. A. Shipp, R. P. W. Duin, "Is independence good for combining classifiers?," in Proc. Int. Conf. Pattern Recognition (ICPR), Vol. 2, Barcelona, Spain, 2001, pp. 168-171
- [9] L. Hong, A. K. Jain, "Integrating faces and fingerprints for personal identification," IEEE Trans. Pattern Analysis Machine Intell., Vol. 20, pp. 1295-1307, December 1998
- [10] A. K. Jain, A. Ross, "Multibiometric Systems", Appeared in Communication of the ACM, Special Issue on Multimodal Interfaces, Vol. 47, No.1, pp. 34-40, January 2004
- [11] Boyce, A. Ross, M. Monaco, L. Hornak, and X. Li, "Multispectral iris analysis: a preliminary study," Proc. of IEEE Computer Society Workshop on Biometrics at CVPR, pp. 51-59, 2006.
- [12] J. S. Pierrard and T. Vetter. Skin detail analysis for face recognition. In Proc. CVPR, pages 1–8, 2007.
- [13] Usher, Y. Tosa, and M. Friedman, "Ocular biometrics: simultaneous capture and analysis of the retina and iris," Advances in Biometrics: Sensors, Algorithms and Systems, Springer Publishers, pp. 133-155, 2008.

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- [14] B. Fernando, M. Glasston, L. Eduardo, H. C. Paulo, and A. Gaurda, "Exploring the scalability of multiple signatures in iris recognition using GA on the acceptance of frontier search," in 2017 IEEE Congress on Evolutionary Computation (CEC), pp. 1843–1847, San Sebastian, Spain, 2017.
 - [15] S. Velmurugan and S. Selvarajan, "A multimodal authentication for biometric recognition system using hybrid fusion techniques," Cluster Computing, vol. 22, no. S6, pp. 13429–13436, 2019.
 - [16] S. Viriri and J. Tapamo, "Iris pattern recognition based on cumulative sums and majority vote methods," International journal of Advanced Robotics Systems, vol. 14, no. 3, p. 172988141770393, 2017.
 - [17] N. Malarvizhi, P. Selavarani, and P. Raj, "Adaptive fuzzy genetic algorithm for multi biometric authentication," Multimedia Tools and Applications, vol. 79, no. 13-14, pp. 9131– 9144, 2020.
 - [18] M. Saracevic, S. Adamovic, and E. Bisevac, "Applications of Catalan numbers and lattice path combinatorial problem in cryptography," Acta Polytechnica Hungarica, vol. 15, no. 7, pp. 91–110, 2018.
 - [19] S. Velmurugan and S. Selvarajan, "A multimodal authentication for biometric recognition system using hybrid fusion techniques," Cluster Computing, vol. 22, no. S6, pp. 13429– 13436, 2019.
 - [20] B. K. Gul and Ç. Kurnaz, "The impact of coding and noise on iris recognition system performance," in 2016 24th Signal Processing and Communication Application Conference (SIU), Zonguldak, Turkey, 2016