

Module 2

Biometric Modalities

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Section 1: Characteristics of Biometric Modalities

This section is designed to help students:

- Identify physical versus behavioral characteristics of various biometrics.
 - Explain challenges and constraints related to biometric modalities.
 - Describe the distinction between genotypic and phenotypic characteristics.
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This section provides an overview of physical versus behavioral biometric modalities as well as considerations of these modalities as they relate to various biometrics applications and system challenges. The section also reviews the terms genotypic and phenotypic and their relationship to physical and behavioral biometric characteristics.

✦ Topic a: Physical versus Behavioral

All biometric traits depend somewhat upon both behavioral and biological characteristics. However, by looking at the various biometric modalities, two basic categories can be identified: physical (or passive) and behavioral (or active).

- **Physical:** Acquiring physical biometric samples involves taking a bodily measurement from subjects. This does not necessarily require any specific action by the subject. As described in the National Science and Technology Council’s “Biometrics ‘Foundation Documents,’” a physical biometric trait is based primarily on an anatomical or physiological characteristic rather than a learned behavior. Examples of physical biometric modalities include fingerprint and iris recognition.
- **Behavioral:** Acquiring behavioral biometric samples requires subjects to be active. They must perform a specific activity in the presence of a sensor. The NSTC “Biometrics Glossary” notes that a behavioral trait is learned and acquired over time rather than based on biology. Also, it is possible that behavioral biometric systems will be developed with a design constraint whereby the system “learns” deviations in behavioral traits over time. Examples of behavioral biometric modalities include signature recognition and keystroke dynamics.

Suitability of modalities

The difference between physical and behavioral biometric modalities can be of great importance in terms of potential applications. We will examine two aspects to demonstrate the differences in suitability between biometric modalities:

- **Identification**

In identification systems, where the input biometric sample has to be compared against many identities in the database, the use of physical characteristics such as a fingerprint or an iris may be more relevant than behavioral traits such as a gait or a signature. This is because behavioral characteristics are more vulnerable to changes in the user's emotional and physical state. Also, they may not exhibit the same level of consistency and uniqueness observed in physical traits.

- **Ease of acquisition**

Another important application regarding the use of biometric modalities is ease of acquisition. This refers to whether biometric samples can be acquired under different operational, environmental, and geographical conditions with sufficient quality and in adequate quantities. For example, it may be difficult to implement speaker recognition in an environment such as a factory where noisy machinery is in use. However, using signature verification for access control to a building seems impractical because biometric subject data must be verified frequently and at numerous points of entry.

Challenges of modalities

No single biometric can meet the requirements of all applications. Thus, no biometric is optimal. The match between a specific biometric and an application is determined by the operational mode of the application and the properties of the biometric characteristic.

Different applications and environments encounter different constraints. For example, acceptable fingerprint samples require user cooperation but a face image can be captured by a surveillance camera.

The effectiveness of a biometric system relies on how and where it is used. Before implementing a system, evaluate the strengths and weaknesses of each biometric modality relative to its application.

Key factors for selecting a biometric system include:

- Evaluating the environment.
- Throughput needs.
- Population size and demographics.
- Ergonomics.
- Interoperability with existing systems.
- User considerations (e.g., cultural issues).

Also, careful evaluation of key challenges associated with each biometric modality plays an important role in the success of the selected technology. Exhibit 2-1 lists challenges related to specific physical and behavioral modalities.

Exhibit 2-1: Challenges by Operational Biometric Modality

Modality	Challenge
Physical Modality	
Face	It is debatable whether the face, without additional contextual information, is a sufficient basis for recognizing a person amid a large number of identities with a high level of confidence.
Iris	Iris recognition is difficult to perform at a distance or with uncooperative subjects. As with other image-based biometric modalities, iris recognition is susceptible to poor image quality, resulting in increased failure-to-enroll (FTE) rates. For forensic applications, latent iris evidence is not deposited at crime scenes. This makes iris recognition less useful than fingerprints and DNA for forensic identification.
Fingerprint	Fingerprint recognition systems require a large amount of computational resources, especially when operating in identification mode. Also, fingerprints of a fraction of the population may be unsuitable for automatic identification because of genetic factors, aging, and environmental or occupational reasons (e.g., laborers with numerous cuts on fingerprints that keep changing).
Hand/finger geometry	The geometry of the hand is not known to be very distinctive, and recognition systems based on hand geometry cannot be scaled up for systems requiring identification of an individual from a large population. Further, hand geometry information may change as children grow.
Behavioral Modality	
Gait	Gait may change, especially over a long period of time, due to fluctuations in body weight, major injuries involving joints or the brain, or intoxication.
Keystroke	Keystrokes are not unique to each individual, but they offer enough discriminatory information to permit identity verification. There may be significant variations in typical typing patterns for some individuals.
Signature	Signatures change over time and are influenced by physical and emotional conditions. Some people's signatures vary substantially; even successive impressions may be significantly different. Further, forgers may be able to reproduce signatures that circumvent the system.

Note: See Module 6, “Biometrics Applications,” for a detailed discussion of the modalities listed above.

✦ Topic b: Genotypic versus Phenotypic

Genotypic versus phenotypic characteristics are based in genetics, and parallels may be drawn to physical versus behavioral characteristics. The term *genotype* refers to a subject’s entire scope of hereditary information, even if it is not expressed in an observable form. The term *phenotype* refers to a subject’s observable properties such as behavior.

Genotypic traits are completely determined by genetics. With regard to data privacy, genotypic information seems to be the most ethically controversial since it may reveal the subject’s relationships to other persons, his or her race, or a possible disease. Phenotypic biometric traits, in contrast, are based on features or behaviors that are acquired through experience and development.

A phenotypic biometric trait is initially affected by an individual’s unique genetic makeup, but it is also affected by the individual’s environment. For example, characteristics such as fingerprints and iris structures may be affected by environmental factors encountered by a fetus in the prenatal environment. Thus, biological organisms are generally the consequence of the interaction of genes and environment.

✦ Progress Check

The following questions are included as study aids and may not follow the format used for questions in the CBP examination. Read each question and respond in the space provided. Answers and page references appear on the following page.

1. All biometric characteristics depend somewhat on both behavioral and biological characteristics.
 a. True
 b. False

2. When considering the suitability of a biometric modality, which aspect of the following is concerned with whether biometric samples can be sufficiently acquired under different operational, environmental, and geographical conditions?
 a. Verification
 b. Cross-matching
 c. Identification
 d. Ease of acquisition

3. In what regard are behavioral characteristics more vulnerable to changes?
 a. There is an increased chance of reference data corruption.
 b. They depend on the subject's emotional or physical state.
 c. It is harder to capture accurate raw data than for physical characteristics.
 d. They are used in covert applications.

4. List three key decision factors for selecting a biometric system.

5. Which physical modality encounters debate about whether it can confirm a subject's identity without additional contextual information?
 a. Finger/hand geometry
 b. Face
 c. Fingerprint
 d. Ear

Progress check answers

1. a (p. 2-1)
2. d (p. 2-2)
3. b (p. 2-2)
4. Evaluating the environment, throughput needs, population size and demographics, ergonomics, interoperability with existing systems, and user considerations are all factors. (p. 2-3)
5. b (p. 2-3)