CAR ACCESS USING MULTIMODAL BIOMETRICS

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Abstract:
This paper presents the use of multimodal biometrics in order to identify or to verify a person that wants to start the engine of a car. First of all, a fingerprint sensor is posted on the car's door, one on the steering wheel, a camera for iris recognition on the car's main mirror, and finally a microphone for voice recognition. There are two possibilities: if the person is identified as the car owner or a known user, then he/she can take control over the car; if it's an intruder, the car can announce the security service or the police using a complex GPRS system.

Keywords: multimodal, biometrics, iris, fingerprint, car, access, control

JEL Classification: C80

1. INTRODUCTION

The use of multi-modal biometrics aims to increase the accuracy of the verification or identification of people. There are a lot of biometric technologies, like iris, face, fingerprint, hand geometry, and voice recognition etc. Each technology has different advantages and disadvantages, and there are some characteristics that every method has such as universality, uniqueness, permanence, collectability, performance, acceptability etc. Some characteristics are better for some technologies at a medium or low level.

The problem in using multi-modal biometrics is the choice the biometric technologies to be used in the system. Also, the person to be identified must pass all the tests, and every test can have a different weight in the system.

2. SHORT HISTORY OF AUTOMATIC IDENTIFICATION

The most used identification activity in criminology and in common civil applications is the one which has as its aim personal identification. The identification of a person that has committed a crime has been made for a long time by using scientific and mystical elements.

One of the most important innovation in personal recognition and registration belongs to Alphonse Bertillon, police functionary in France, who claimed and demonstrated in 1879 that if many body dimensions – such as waist, width, height, head circumference, the height of right ear, the length of some phalanges and of some bones from the left hand – are measured, then it would be almost impossible to find two individuals with the same characteristics.

It is probably the first "anthropometrical" identification and verification system. This can also be considered as a multimodal biometric system, as it uses many characteristics of the human body. These researches were the first in this important field.

3. MODERN BIOMETRIC SYSTEMS

Decades ago, when the first biometric technologies were developed, they were much too expansive and complex, being used only in military applications that needed a very high level of security.

The situation changed dramatically because of the progress of informatics technologies and also because of the explosive growth of frauds –it is estimated that every year in the USA, because of the ATM frauds, there are abound 500 million dollars lost, 2 billion dollars in the case of cheques, and 1.5 billion dollars from credit cards.

The use of PINs and passwords are not useful anymore for the identification of a person. It is demonstrated, especially in the USA, that if a single document, such as a driving license, is less secure, then all the documents can be obtained by using this counterfeit act.

The following picture shows the percentage of the main fields where the biometrical technologies are used.

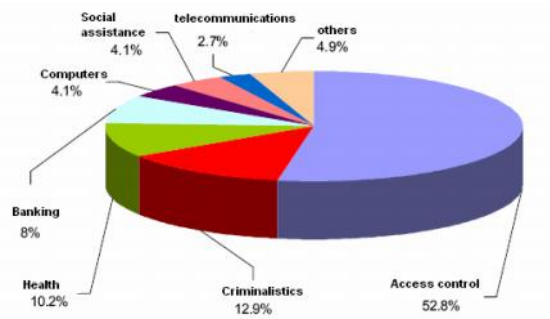


Figure 1. The use of biometric technologies

There are many physiological characteristics traditionally used for identification. The biometric indices can be classified in the following main categories:

- general look/appearance (e.g. height, weight, the color of the skin, hair or eyes, visible characteristic signs, gender, race, facial hair, etc.; all these can be presented in a photo);
- behavior (e.g. general characteristics of the voice, type of character, visible handicaps, features recorded on video tape, etc)
- bio-dynamic elements (e.g. the pressure and the speed of signature, static characteristics of the voice, speed of typing, etc.)
- natural physiological elements (e.g. the dimensions of the skeleton – anthropometrics, healed fractures of the bones, fingerprints and palm-prints, vein structure, iris and retina image, the model of the ear, hand geometry, DNA, etc)
- artificial elements (used especially for the recognition of animals: bracelets, tattooed bar codes, chips implanted under the skin, etc.)

Some of these elements, like hair color, weight and height, modify naturally throughout time. The main characteristics of an ideal identification system are presented below:

- universality – every person must be identifiable after the proposed criteria;
- uniqueness – every person must have a single identifier; there should not exist two persons with the same identifier;
- permanence – the identifier must not change during the time, or to be transformed at individual wish;
- necessity – the identifier must contain one or more natural characteristics, at which one person cannot renounce;
- acquisition – the identifier must be easily obtained;
- conservation – the characteristic must be easily stored, in manual or automatic identification systems;
- precision – every identifier must be different enough from another, so that the recognition is made without error.

- cost – the collection and storage of the characteristics must be cost-effective;
- acceptability – the users must agree that the identifier be collected and stored in a database.

In figure 2 is presented the weight of the most used biometric technologies.

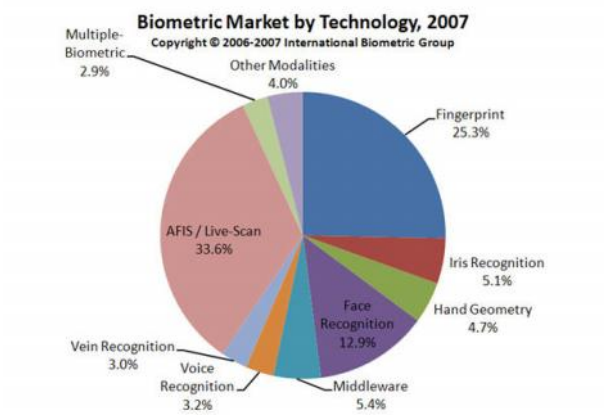


Figure 2. The weight of the biometric technologies

It can be seen from this picture that the main biometric technologies are based on fingerprinting and hand geometry. But, for better accuracy, iris scan can be used, because it's relatively cheap and the results are very promising. The speed of the verification or identification is very small, and the accuracy and uniqueness are at a very high level.

4. DESCRIPTION OF THE BIOMETRIC TECHNOLOGIES USED IN THE CAR ACCESS CONTROL

The main biometrics identifiers used in this system are fingerprint, voice, and iris recognition. In the following paragraphs there will be presented the main characteristics of each identifier.

4.1. FINGERPRINT RECOGNITION

This method is probably the most used in personal recognition. It is also one of the first methods of identification and verification. The police use this method to find people who committed different crimes. But this method can be used in civil applications in order to identify the persons. It can be used especially in the access control applications.

The use of fingerprints for identification presents a series of advantages, such as:

- there exists a very significant experience in the use of fingerprints for identification;
- the primary information can hardly be counterfeited, though it is still possible;
- the quantity of information that must be stored is not very high;
- algorithms for processing the fingerprints are very simple, using only 2D mathematical models;
- the price for acquiring the fingerprints is the smallest of all the biometric equipments;

- the precision of personal identification is very well;
- it is a completely non-invasive method;
- identification time is under one second.

The informatics technique used for the recognition of persons is generically called AFIS (*Automatic Fingerprint Identification System)*. The procedure starts with the acquisition of the fingerprint image, then the system automatically marks the zones of interest for the description of the ridges on the image; the points marked on the fingerprint are stored as Cartesian coordinates and are compared with the coordinates stored in the database.

In the following picture it is presented the fingerprint with the points of interest marked and a capacitor sensor for image acquisition.

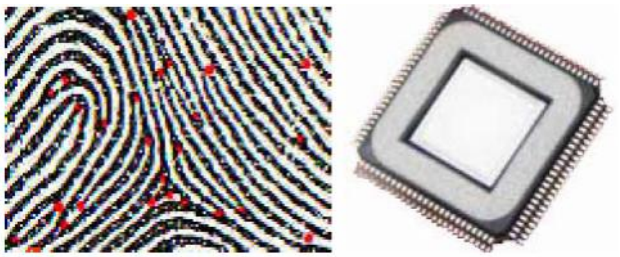


Figure 3. The fingerprint with interest points marked and a sensor for the image acquisition

4.2. IRIS RECOGNITION

Mr. John Daugman, from the Cambridge University, developed the main algorithms in iris recognition.

Iris recognition is one of the most accurate methods of personal identification and verification.

Many companies implemented his method in their software products and created special camera for the acquisition of the image. For example, the Panasonic BM-ET330 is presented below.

Figure 4. Panasonic BM-ET330

The image of the iris is acquired from an iris camera, and then is filtered and recognized in order to obtain a code called IrisCode, which has only 512 bytes. The comparison between two irises is made by calculating the Hamming distance between two codes. This procedure is extremely rapid.

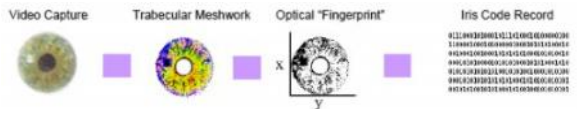
Iris recognition today combines technologies from several fields including, computer vision (CV), pattern recognition, statistical interference, and optics. The goal of the technology is near-

instant, highly accurate recognition of a person's identity based on a digitally represented image of the scanned eye. The technology is based upon the fact that no two iris patterns are alike (the probability is higher than that of fingerprints). The iris is a protected organ which makes the identification possibilities life long. The iris can therefore serve as a life long password which the person must never remember. Confidence in recognition and identification facilitates exhustive searches through nation-sized databases.

Iris recognition technology looks at the unique characteristics of the iris, the colored area surrounding the pupil. While most biometrics have 13 to 60 distinct characteristics, the iris is said to have 266 unique spots. Each eye is believed to be unique and remain stable over time and across environments (e.g., weather, climate, occupational differences).

Iris recognition systems use small, high-quality cameras to capture a black and white high-resolution photograph of the iris. Once the image is captured, the iris' elastic connective tissue-called the trabecular meshwork-is analyzed, processed into an optical "fingerprint," and translated into a digital form. Figure 12 depicts the process of generating an iris biometric. Given the stable physical traits of the iris, this technology is considered to be one of the safest, fastest, and most accurate, noninvasive biometric technologies. This type of biometric scanning works with glasses and contact lenses in place. Therefore, iris scan biometrics may be more useful for higher risk interactions, such as building access. Improvements in ease of use and system integration are expected as new products are brought to market.

The iris is differentiated by several characteristics including ligaments, furrows, ridges, crypts, rings, corona, freckles, and a sigzag collarette.



Iris recognition technologies are now seen in a wide array of identification systems. They are used in passports, aviation security, access security (both physical and electronic), hospitals, and national watch lists. Iris recognition alogithms can be seen in more and more identification systems relating to customs and immigration. Future applications will include, e-commerce, information security (infosec), authorisation, building entry, automobile ignition, forensic applications, computer network access, PINs, and personal passwords.

Advantages of the Iris for Identification

- Highly protected, internal organ of the eye
- Externally visible; patterns imaged from a distance
- Iris patterns possess a high degree of randomness
- variability: 244 degrees-of-freedom
- entropy: 3.2 bits per square-millimeter
- uniqueness: set by combinatorial complexity
- Changing pupil size confirms natural physiology
- Pre-natal morphogenesis (7th month of gestation)
- Limited genetic penetrance of iris patterns
- Patterns apparently stable throughout life
- Encoding and decision-making are tractable
- image analysis and encoding time: 1 second

- decidability index (d-prime): d' = 7.3 to 11.4
- search speed: 100,000 IrisCodes per second on 300MHz CPU

Disadvantages of the Iris for Identification

- Small target (1 cm) to acquire from a distance (1 m)
- Moving target ...within another... on yet another
- Located behind a curved, wet, reflecting surface
- Obscured by eyelashes, lenses, reflections
- Partially occluded by eyelids, often drooping
- Deforms non-elastically as pupil changes size
- Illumination should not be visible or bright
- Some negative (Orwellian) connotations

4.3. VOICE RECOGNITION

Voice biometrics works by digitizing a profile of a person's speech to produce a stored model voice print, or template. Biometric technology reduces each spoken word to segments composed of several dominant frequencies called formants. Each segment has several tones that can be captured in a digital format. The tones collectively identify the speaker's unique voice print. Voice prints are stored in databases in a manner similar to the storing of fingerprints or other biometric data.

To ensure a good-quality voice sample, a person usually recites some sort of text or pass phrase, which can be either a verbal phrase or a series of numbers. The phrase may be repeated several times before the sample is analyzed and accepted as a template in the database. When a person speaks the assigned pass phrase, certain words are extracted and compared with the stored template for that individual. When a user attempts to gain access to the system, his or her pass phrase is compared with the previously stored voice model. Some voice recognition systems do not rely on a fixed set of enrolled pass phrases to verify a person's identity. Instead, these systems are trained to recognize similarities between the voice patterns of individuals when the persons speak unfamiliar phrases and the stored templates.

A person's speech is subject to change depending on health and emotional state. Matching a voice print requires that the person speak in the normal voice that was used when the template was created at enrollment. If the person suffers from a physical ailment, such as a cold, or is unusually excited or depressed, the voice sample submitted may be different from the template and will not match. Other factors also affect voice recognition results. Background noise and the quality of the input device (the microphone) can create additional challenges for voice recognition systems. If authentication is being attempted remotely over the telephone, the use of a cell phone instead of a landline can affect the accuracy of the results. Voice recognition systems may be vulnerable to replay attacks: if someone records the authorized user's phrase and replays it, that person may acquire the user's privileges. More sophisticated systems may use liveness testing to determine that a recording is not being used.

Consumer voice recognition systems are typically inexpensive and user-friendly. Most computer systems are equipped to support a microphone used to develop a voice template and later to collect the authentication request. Voice recognition is more often used in an environment in which voice is the only available biometric identifier, such as in telephony and call-center applications. Voice recognition systems have a high user acceptance rate because they are perceived as less intrusive and are one of the easiest biometric systems to use.

Voice verification technology uses the different characteristics of a person's voice to discriminate between speakers. These characteristics are based on both physiological and behavioral components. The physical shape of the vocal tract is the primary physiological component. The vocal tract is made up the oral and nasal air passages that work with the movement of the mouth, jaw, tongue, pharynx and larynx to articulate and control speech production. "The physical characteristics of these airways impart measurable acoustic patters on the speech that is produced," as one expert explained.91 The behavioral component is made up of movement, manner, and pronunciation.

The combination of the unique physiology and behavioral aspects of speaking enable verification of the identity of the person who is speaking. Voice verification technology works by converting a spoken phrase from analog to digital format and extracting the distinctive vocal characteristics, such as pitch, cadence, and tone, to establish a speaker model or voiceprint. A template is then generated and stored for future comparisons.

Voice verification systems can be text dependent, text independent, or a combination of the two. Text dependent systems require a person to speak a predetermined word or phrase. This information, known as a "pass phrase," can be a piece of information such as a name, birth city, favorite color or a sequence of numbers. The pass phrase is then compared to a sample captured during enrollment. Text independent systems recognize a speaker without requiring a predefined pass phrase. It operates on speech inputs of longer duration so that it has a greater opportunity to identify the distinctive vocal characteristics (i.e., pitch, cadence, tone).

Voice verification systems can be used to verify a person's claimed identity or to identify a particular person. It is often used where voice is the only available biometric identifier, such as over the telephone. Voice verification systems may require minimal hardware investment as most personal computers already contain a microphone. The downside to the technology is that, although advances have been made in recognizing the human voice, ambient temperature, stress, disease, medications, and other physical changes can negatively impact automated recognition.

Voice verification systems are different from voice recognition systems although the two are often confused. Voice recognition is used to translate the spoken word into a specific response, while voice verification verifies the vocal characteristics against those associated with the enrolled user. The goal of voice recognition systems is simply to understand the spoken word, not to establish the identity of the speaker. A familiar example of voice recognition systems is that of an automated call center asking a user to "press the number one on his phone keypad or say the word 'one'." In this case, the system is not verifying the identity of the person who says the word "one"; it is merely checking that the word "one" was said instead of another option.

5. INTRODUCTION TO MULTIMODAL BIOMETRIC SYSTEMS

Biometrics has been adopted in a variety of large-scale identification application -- ranging from border control to voter ID issuance. While the technology is conceptually adept, in reality there are numerous challenges associated with enrolling large populations using just single (unimodal) biometrics. These challenges can be overcome by deploying multimodal biometrics systems.

5.1. THE PROBLEMS WITH UNIMODALITY

The shortcoming of unimodal biometrics is that no one technology is suitable for all applications. Therefore, the presence of a multimodal biometric system helps compensate for the following limitations:

- The usage of certain biometrics makes it susceptible to noisy or bad data, such as inability of a scanner to read dirty fingerprints clearly. This can lead to inaccurate matching, as bad data may lead to a false rejection.
- Unimodal biometrics is also prone to inter-class similarities within large population groups. In case of identical twins, a facial recognition camera may not be able to distinguish between the two.
- Some biometric technologies are incompatible with a certain subset of the population. Elderly people and young children may have difficulty enrolling in a fingerprinting system, due to their faded prints or underdeveloped fingerprint ridges
- Finally, unimodal biometrics are vulnerable to spoofing, where the data can be imitated or forged.

5.2. DEFINITION OF MULTIMODALITY

Multimodality is the usage of more than one physiological or behavioral characteristic to identify an individual. It involves the fusion of two or more technologies such as fingerprint, facial recognition, iris scanning, hand geometry, signature verification, or speech recognition.

The fusion is done by running the two (or more) biometric inputs against two (or more) different algorithms, to arrive at a decision. This technique is useful in large-scale civil ID applications, where the identity of thousands of people need to be authenticated at a time. To have an additional method of verification as a backup reduces the possibility of inconveniences caused by the malfunctioning of the primary biometric.

5.3. ADVANTAGES OF MULTIMODALITY

It is estimated that approximately 5 percent of any population has unreadable fingerprints, either due to scars or aging or illegible prints. In a civil ID scenario, where millions of people have to be enrolled in the system, the segment of the population who are un-enrolable will face inconveniences. Having multimodal biometric technology can overcome this restriction and ensure lower failure to enroll rate (FTE).

Multimodality can also address the problem of aversion to fingerprinting, found in certain parts of the world. Sometimes people associate fingerprints with criminal activity, and are reluctant to submit prints. By having an additional biometric available, a greater number of people can be enrolled into the system

Using multiple biometrics solves the problem of inter-class similarity and the resultant high false acceptance rate (FAR). If people with similar hand sizes or similar looking facial features can gain false acceptance, the presence of another biometric such as signature verification can distinguish between the samples.

Another advantage of using multimodality is that it solves the problem of data distortion. If the quality of one of the biometric samples is unacceptable, the other can make up for it. If a fingerprint has been scarred and the scanner rejects the distorted sample, having another modality like facial recognition can prevent high false rejection rates (FRR).

Unimodal Biometrics can be easily spoofed. Placing a high-resolution picture of a fingerprint under the scanner can deceive some systems. However, by using multiple biometrics, even if one modality could be spoofed, the person would still have to be authenticated using the other biometric. Besides, the effort required for forging two or more biometrics is a deterrent to those who wish to do so.

5.4. DISADVANTAGES OF MULTIMODALITY

Some of the disadvantages of multimodality include:

- Interoperability and Standardization: The technology is at its early stages, and there are no universal standards set for storing templates and having all biometrics technologies seamlessly work together.
- Cost: The addition of another biometric technology can drive up the price of the solution. Critics of multimodal systems say it does not offer real value, and that it is just a marketing gimmick geared toward increasing sales.
- Reduced Matching Level: Calculations provided by John Daugman, the originator of the iris algorithm, claim that if a stronger biometric is used in conjunction with a weaker biometric, the result is not necessarily a stronger combined system. The error rate (FAR or FRR) of the weaker biometric can bring down the overall effectiveness of the system.

Major biometrics companies have released products that combine multiple biometrics, mainly for large-scale civil ID usage. Motorola's biometrics unit offers a 'multi-biometric' enrollment and verification solutions with support for fingerprinting, 2D/3D facial recognition, and signature verification. ImageWare Systems also has a middleware product called 'Biometric Engine' that can capture finger, face, and iris data to be used for passport and national ID issuance. Viisage was selected to implement an integrated finger and face biometric system for Iceland's e-passport program. Rather than relying on paper-based images, the facial recognition technology will be used to store a photograph in the passport chip. This will offer higher quality and accuracy levels. The state of Qatar in May 2006, announced the rollout of a national identification project, which will store fingerprint, face, and iris biometric data on a smart card. Similar integration of multiple biometrics with smart card-enabled ID documents is being implemented around the world.

5.5. FUTURE TRENDS

So far, the prominent biometrics combinations have been fingerprint, facial, and iris recognition. It is possible that the patent issue surrounding hand geometry has made it less accessible for union with multimodal systems. An interesting trend has been the acquisition of companies focusing on a particular biometric technology by companies that make other biometrics. Identity solutions company Viisage, in January 2006, entered into an agreement to merge with Identix, who makes fingerprint scanners. Viisage also acquired the iris recognition company Iridian Technologies, thus becoming competent in facial, fingerprint, and iris biometrics. Similarly, Cross Match Technologies bought out the facial recognition technology company C-VIS, in order to provide multi-modal biometric offerings to their customers. It will be interesting to see if offering a multimodal product triggers the next wave of development within the market, or if it is just a short-term marketing gimmick.

6. THE CAR ACCESS CONTROL PROCESS DESCRIPTION

In this application there are used three main characteristics. The user who wants to use a car must pass all the four tests. First, on the car door there must be a fingerprint reader, then another one on the steering wheel. A microphone records the voice of the user then an integrated chip analyzes these signals. A specialized iris camera takes the iris image and processes it in order to obtain an IrisCode. This code must be compared with the ones stored in a local database. The camera can be placed at the back of the car’s main mirror, or it can stay on the board.

After the user passes all this tests, he/she can start the engine of the car. If the user doesn't pass one test, then it can be repeated. After a second attempt, if the test fails, then all collected data is sent by using an integrate GPRS system to the police or/and to an authorized user of the car.

Then, the police can identify the person if his/her characteristics are stored in a database, or can store his fingerprints, voice and iris in a database of criminals.
The main user of the car can introduce other persons in the database by acquiring their images of the fingerprint, voice and iris.

For higher security, both irises can be stored in the database, or more fingers. Of course, many other methods can be combined in order to increase the accuracy of the identification process. Another possibility can be figured out: if the person doesn't possess one biometric identifier, then another one can be used, having in this case a backup biometric identification system. For example, if the person can't talk, then this disability will be stored in the system and only fingerprint and iris verification will work for that person.

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