Hand-geometry device

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Synonyms

Hand-geometry reader, Hand-geometry scanner, Hand-scanning device

Definition

Hand-geometry devices are specially designed biometric devices used for capturing the geometric characteristics (e.g., the length, width, thickness and curvature of the fingers, the palm size, and the distances between joints) of a human hand for hand-geometry-based identity verification. A typical hand-geometry device records images of the lateral and dorsal parts of the hand with a charge-coupled device (CCD) camera that is mounted above a flat surface on which the person presented to the device places his/her hand. The set of geometrical features extracted from these images is then matched against a pre-recorded template stored in the device's database. Depending on the result of this matching procedure, the identity of the person presented to the device is either verified or not.

Main Body Text

Introduction

Hand-geometry devices are among the earliest commercially available biometric devices for automated identity verification. [1]. The production and distribution of the first commercial hand-geometry device, called the Identimat, was launched in the early 1970s by the Identimation Corp., which adopted a hand-reader concept developed and patented by Robert P. Miller [2]. Like with Miller's original design, Identimation's device used spatial characteristics of the index, middle, ring and little fingers as the means of establishing the identity of a person. It utilized a number of electromechanical components and photoelectric cells to measure the length of the four digits and compare them to finger-length measurements that were previously recorded and stored on an identification card. The device was very well received on the market and was eventually installed for access-control purposes at several high-security facilities run, for example, by the U.S. Department of Energy, Western Electric and U.S. Naval Intelligence [3].

Encouraged by the success of Identimation's hand-based verification system and the growing demand for reliable and user-friendly verification schemes, several other companies tried to enter the hand-biometry market during the 1970s and early 1980s. They developed numerous prototypes, using ideas and device designs from early patents (e.g., [2, 4, 5]); however, most of them never actually made it to the market. One of the few exceptions was the ”3D hand profile identification apparatus” devised by David Sidlauskas [6]. His device featured a **platen** on which a person placed his/her hand and a digital camera that captured images of the hand's side and top views. Discriminative hand characteristics extracted from these images were then employed for the identity verification. Unlike previously developed hand-geometry readers, Sidlauskas' device did not rely solely on two-dimensional measurements of the hand, but used **orthographic scanning** to capture the hand's three-dimensional structure. Later manufactured under the commercial name ID3D by Recognition Systems Inc. (RSI) [7], it became an important milestone in the field of hand-geometry-based verification and is, albeit in a much refined form, still on the market today.

By the late 1990s manufacturers of commercial hand-geometry devices (such as RSI) were the only driving force in the development of hand-geometry-based biometric technology. However, in the past decade, due to advancements in the fields of biometrics and computer vision, the academic community has taken a more active role in the development of hand-geometry devices, e.g., [1, 8, 9, 10].

Description of the device

Unlike early hand-geometry devices, (e.g., [2, 4]), which were primarily based on electro-mechanical components, modern devices, such as the one presented in Fig. 1, use imaging technology and internal software to capture and process the images of a person's hand and to extract the geometrical features, e.g., the lengths, widths, thicknesses and curvatures of the fingers, and the width, thickness and area of the palm, that are used for the identity verification.

Fig. 1. A commercial hand-geometry device [7] (courtesy of Recognition Systems Inc.)

The basic design and use of a hand-geometry device is quite simple. When a person places his/her hand on the device's reflective, flat surface, referred to as the platen, he/she first has to align his/her fingers with a number of guiding pegs that direct the hand to a predefined position. The pegs are equipped with pressure sensors which, when enough pressure is applied to them, simultaneously trigger the charge-coupled device (CCD) camera (commercial devices typically use a 32,000 pixel CCD camera) and the infrared light source (e.g., light emitting diodes) positioned above the device's platen. The platen then reflects the emitted light back to the camera and an image is recorded. However, as parts of the platen are covered with the person's hand, some of the infrared light is absorbed and only a silhouette is visible in the resulting image [11, 12, 13]. Due to the design of modern hand-geometry devices, which feature a side-mounted mirror inclined at 45° to the platen, the acquired silhouette image contains both the shape of the dorsal (i.e, the top view) as well as the lateral (i.e., the side view) surface of the hand [9]. Once recorded, internal software extracts a number (more than 90 in commercial devices) of geometrical features from the silhouette image and uses them to verify the identity of the person presented to the device.

However, before a person can use the device, he/she first has to enroll. During the enrollment phase the device captures several images of the person's hand, extracts geometrical features from each of these images and uses them for the calculation of the template. The template is then stored in the device's memory or on an identification card (i.e., a **smart card**) and is later retrieved for comparison. A similar procedure is required when a person presented to the device is trying to verify his/her identity. First, the person claims an identity by entering a personal identification number (PIN) or by swiping an identification card (depending on the input mechanism provided by the device at hand) through a card-reader module connected to the device. The device then proceeds with the image-acquisition and feature-extraction stages and finally recalls (either from an internal memory or from the smart card) the template associated with the claimed identity, for comparison. In the final step a matching procedure is applied to decide whether or not the person presented to the device is who he/she claims to be [7, 9, 11, 12]. In the case of a positive decision, i.e., the identity of the person is verified, the device usually updates the template to account for possible changes in the geometry of the person's hand (which is especially important when the device is used by children, whose hand-geometry is changing fast) and stores a new template for future verification attempts in the device's memory (or ID card). This process is commonly referred to as template averaging [11].

While typical hand-geometry devices are designed to be used in conjunction with the right hand, it is possible for a person to enroll and verify his/her identity using the left hand. In this case, the (left) hand is placed on the platen with the palm facing upwards [11]. As only the geometry of the hand is of significance, this has no negative effect on the verification accuracy of the device.

There are also commercial devices available on the market that do not use the geometry of the whole hand to verify the identity of a person, but accomplish this task based on measurements of only two fingers.

The main part of the device is a camera-based sensor that uses three-dimensional scanning technology to capture the structure of the index and middle finger (of either hand) of the person presented to the device. From these scans a set of geometrical features is extracted and matched against a template recorded during the enrollment session. Depending on the outcome of the matching procedure, the identity of the person presented to the device is either verified or not [14].

Research trends

In recent years many research groups from private companies as well as academic institutions have directed their research towards hand-geometry-based identity verification. They are developing new verification schemes that require new kinds of hand-geometry devices, different from those available on the market today. The main trend at present is to design devices that require no pegs to control the placement of the hand. These designs, like the current commercial devices, still feature a platen upon which the person places his/her hand. However, as there is no guiding mechanism, the hand is simply positioned on the platen with the fingers spread naturally. A CCD camera or a digital scanner then captures images of the hand from which pose-independent geometrical features are extracted and used to verify the identity of the person presented to the device [10]. Peg-free designs are commonly considered to have a number of advantages over classical hand-geometry devices: first, they do not cause any deformations of the hand's silhouette shape as no contact with the guiding pegs occurs; second, they reduce the chances of the person incorrectly positioning his/her hand; and third, they allow people with small hands , e.g., children, who might have problems reaching all the pressure sensors of current commercial devices and so are unable to initiate the verification procedure, to use the device. Although numerous experimental designs following the described trend were presented in the literature, none of them has yet succeeded in passing the prototype stage [9, 10].

Characteristics

Over the past thirty years hand-geometry-based recognition has become one of the most popular biometric technologies for physical access control and time-and-attendance applications. The broad success of hand-geometry devices in these specific application areas was triggered by various human and operational factors, among which the following are the most important [9]:

- *User acceptance:* Hand-geometry devices offer a fast, easy to use and fairly reliable method of user authentication, and are therefore enjoying a relatively high level of public acceptance. A survey conducted by the Sandia National Laboratories [15] in 1991 reported that most of the test subjects favored hand-geometry devices over other devices based on fingerprint, signature, retina or face biometrics.
- *Functionality:* Hand-geometry devices can operate in harsh environmental conditions and are therefore suitable for indoor as well as outdoor deployment [10]. Furthermore, as they rely only on the geometric structure of the hand, while ignoring its surface details, they are to some extent insensitive to the presence of dirt or dust, which makes them a preferable choice for access control and time-and-attendance applications in labor-intensive branches such as the construction industry [7].
- *Template size:* The memory requirements for storing a template are the lowest among all biometric technologies. With a size of 9 bytes (or 20 bytes for devices based on the geometry of just two fingers) they are significantly lower than those imposed by other modalities [11, 12]. Such a small size is advantageous for three reasons: first, when a hand-geometry device is operating as a stand-alone unit, it allows a large number of templates to be stored in the device's internal memory; second, it saves processing time; and third, it permits the storage of user-templates on identification cards.
- *Failure to enroll (FTE) and failure to acquire (FTA) rates:* Hand-geometry devices can be used by most of the world's population, except for some individuals that suffer from severe arthritic conditions and are therefore unable to correctly position their hands on the device's platen. For this reason, hand-geometry devices exhibit relatively low FTE and FTA rates, when compared to other biometric devices. A recent study involving 200 participants showed [16] that the FTE and FTA rates for hand-geometry devices were the lowest among all the tested devices (tested were face, iris, vein, voice, hand-geometry and fingerprint scanners).

Although the presented characteristics resulted in the widespread use of hand-geometry devices for access control and time-and-attendance purposes, there are, nevertheless, still a number of shortcomings that limit their use in other application areas, the most significant being:

- *Size:* Typical hand-geometry devices are designed to accommodate the whole human hand (or at least two fingers) and are consequently significantly larger than other devices used for capturing the biometric traits of a person (e.g., face, voice, and fingerprints). This fact makes them unsuitable for security applications, where a compact size for the biometric device is preferable (e.g., laptops and mobile devices) [12].
- *Cost:* Commercial hand-geometry devices can cost considerably more than, for example, fingerprint scanners, which target a similar market segment (i.e., access control and time-and-attendance). With a price of approximately $1000-$2000 they are among the more expensive biometric technologies [9, 12].

- *Performance:* The false-acceptance (FA) and false-rejection (FR) rates for hand-geometry-based security systems are typically higher than those of fingerprint-, palmprint- or iris-based systems, which makes hand-geometry devices suitable only for low/medium security applications. Several independent studies (e.g., [13, 15, 16]) reported that commercial hand-geometry devices achieve FA and FR rates in the range 0.1%-1.0% at the equal-error operating point.

Operation

Commercial hand-geometry devices are capable of operating in two distinct types of configurations: as stand-alone units or as part of a networked system [7, 11, 17].

Stand-alone units: While hand-geometry devices deployed for time-and-attendance monitoring typically require an additional time clock and a computer to record and retrieve information about the arrival and departure times of people, they can, nevertheless, be used for access control purposes without the need for any additional components. A hand-geometry device can, for example, directly control the locking mechanism of a door and release it if the identity of the person trying to gain access to the secured facilities is successfully verified. In this stand-alone configuration the devices are suitable only as access control systems for single doors (e.g., main entrances, doors to sensitive areas such as computer rooms, storage areas, etc.), while a (networked) system of hand-geometry devices is needed when multiple doors have to be secured. The number of people that can be enrolled in a stand-alone device is limited by the storage capabilities of the device, since all user templates are stored locally in the device's internal memory. Furthermore, as no other means are available, for example, a central computer, all administrative tasks have to be preformed with the help of the device's keypad [7, 11, 17].

Networked system: Commercial devices support a number of communication standards and protocols (e.g., RS-485, RS-422, RS-232, and TCP/IP) that can be used to connect an arbitrary number of devices with a host computer to form a networked system. In contrast to stand-alone units, networked systems are commonly employed in applications that require multiple hand-geometry devices (e.g., access control to facilities with several entrances). While these requirements can be met with several stand-alone devices, the use of a networked system has a number of advantages: first, a person does not have to undergo the inconvenience of enrolling at each of the units, but is able to enroll at a single location and retrieve his/her template for comparison from a central storage location at any unit (for which he/she has access rights) of the network; second, all door activities and time (and/or attendance) records can be stored and viewed via a central computer, making system monitoring simple and efficient; and third, a networked system enables the centralized management of user profiles (e.g., their access rights, and deletions) [7, 17].

Commercial devices are also able to emulate standard card-reader units, which makes it easy to integrate them into existing security systems. When employed in the card-reader emulation mode, the hand-geometry device, upon successful verification, simply forwards the user's identification number in an appropriate format to the card-reader module, which then proceeds as if the identification number had been read from an identification card. Several card protocols are commonly supported, the main ones being Wiegand, barcode and magnetic stripe [7, 11, 17]. In fact there are two standards defining the data-interchange formats of hand-geometry devices: the "ANSI INCITS 396-2005 Hand Geometry Interchange format" and its international counterpart the "ISO/IEC 19794-10:2007 Biometric Data Interchange Format - Part 10: Hand Geometry silhouette data". The standards define both the format and the content for the exchange of the hand-silhouette data, and are aimed at increasing the interoperability of hand-geometry devices [18].

Summary

Among the different biometric devices available on the market, hand-geometry devices have emerged as the preferred choice for physical access control and time-and-attendance applications, especially in harsh environments where other devices might have problems in reliably verifying the identity of a person. They are based on a field-proven technology that by today has been in use for more than twenty years. However, research is already on the way to producing the next generation of hand-geometry devices, which will undoubtedly result in smaller, faster and more user-friendly units. Several research groups have already developed prototypes that require no guiding pegs to capture an image suitable for the extraction of hand-geometry features. While these prototypes still need time to mature, they are a clear indication of future trends in the development of hand-geometry devices.

Related Entries

Hand recognition, Hand geometry, Hand anatomy, Biometric sensor and device

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Definitional Entries

Platen

In a hand-geometry device the term platen refers to the flat surface of the hand geometry reader on which the person presented to the device places his/her hand. The platen is usually equipped with a number of pegs (or pins) to guide the placement of the person’s hand and to ensure the accurate measuring of the hand’s geometric structure.

Orthographic scanning

The procedure of recording two-dimensional images of an object with the goal of capturing the object’s three-dimensional structure. In a hand-geometry device, for example, it is performed with the help of a mirror that projects the lateral surface of the hand into the visual field of the camera and allows it to record both the side and top views of the hand in a single image.

Smart card

Synonyms: Integrated circuit card (ICC), Chip card

A smart card is a small, plastic card with an embedded microchip that can store and/or process information. It can receive and submit data to or from any system equipped with an appropriate card-reader module. In commercial hand-geometry devices, for example, smart cards are often used as storage media for user-templates and as such eliminate the need for storing templates in the internal memory of the device.