Analysis of a Hand Geometry-Based Verification System

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ABSTRACT
Hand and finger geometry recognition is the process of identifying an individual through the unique "geometry" (shape, thickness, length, width, etc.) of that individual's hand. Hand geometry recognition systems can be used in several different types of applications, including access control and time and attendance tracking, while time and attendance tracking can be used for security. Biometric systems are widely used for access control, and can be used on various types of assets, including entryways, computers. This paper explores the use of hand geometry as a measure of a person's identity. The system consists of an acquisition device that captures the top view and side view of a user's right hand as he places it on the flat surface of the device. This paper presents an overview of hand geometry system, the benefits and its integration.

Keywords: Biometrics, Security, Hand Geometry, verification

1. Introduction
Biometric is gaining more attention in recent years. There are many biometric systems based on different characteristics and different parts of the human body. Biometric systems that are widely used are based on iris, fingerprint, face, and hand. Each biometric has its strengths and weaknesses depending on its application and utilization [1]. This paper focuses on hand geometry which is one of many effective biometric systems. Hand geometry is a biometric that identifies users by the shape of their hands. Hand geometry readers measure a user's hand along many dimensions and compare those measurements to measurements stored in a file. Hand geometry is very reliable when combined with other forms of identification, such as identification cards or personal identification numbers. Hand geometry is the first biometric to find widespread computerized use.

Over the years, a strong business case has been established for the use of hand geometry for time and attendance, in particular, eliminating the problem of buddy-punching [2]. The readers themselves are able to operate in environmentally challenging situations, although there is little or no change that can be anticipated to the form factor for this technology. [3] Stated that users do not perceive the collection of their hand geometry to be privacy invasive (as they do with fingerprint-related technologies), but the technology is more expensive than alternatives such as fingerprint recognition, but also deemed less accurate than either iris recognition or fingerprint recognition solutions.

Hand geometry recognition security systems are used to positively identify an individual using the unique biological characteristics of their hand.
2. Hand Geometry Applications

Hand geometry recognition security systems is currently among the most widely used biometric technology, it can be used in any application requiring the unique verification of individuals, including time and attendance applications (i.e., tracking when an individual enters and exits a location), or access control applications [4]. Below are some applications of hand geometry based verification system [5].

2.1. Cash Vault Applications
A cash vault mantrap has two door and entry and exit, and a hand scanner inside verifies the entrants. Number of people entering from the public side of mantrap is recorded by a personnel counter and a programmable logic controller reports the count to the hand scanner which must match the number of people using the scanner.

2.2. Dual Custody Applications
In dual custody access control, two different people must verify before the scanner sends an output. Dual custody concept is common in physical security, has several variations and can be translated easily to hand scanner electronic access control.

2.3. Anti-pass Back
A common access control function in which a user is prevented from passing a card to an accomplice. Anti-pass back seems redundant for hand scanner applications as its difficult at best to pass a hand.

2.4. Time and Attendance
The first hand geometry time and attendance installations used hand scanners connected to a printer or access control software to record users’ arrival and departure. This required manual sorting of event data, though some “computer savvy” managers exported event data files to spreadsheet programs where they could sort and calculate the data.

2.5. Point of Scale Applications
For the purpose of identity verification, point of scale application is used, like debit systems are becoming more common in our everyday lives as we move toward being cash less society.

2.6. Interactive Kiosk
Hand scanners have found broad applications in the interactive kiosks. A host computer maintains user files and interacts with the user through a touch screen monitor or keyboard. It checks that user is valid or not, if yes, monitor displays a menu of choices from which the user may select. The interactive kiosk communicates with user after ID entry and verification. An automated border crossing is a popular application of the interactive biometric kiosks.

2.7. Parking Lot Application
Hand scanner used for access control in parking lots will be a welcome by the users as they don’t need to carry cards. However, prevalent hand scanners are designed for use with the right hand making it difficult for left hand driven automobiles or by sports utility vehicles and sports cars which may require platen height to vary by as much as 0.9 meter.

3. Hand Geometry Module
Hand geometry features are processed from an image by three steps as follows: image acquisition, registration and verification of identification. This is illustrated in the diagram below.

![Diagram of a general biometric system](image)

3.1. Image Acquisition
The components of image acquisition devices consist of a light source, a camera, a single mirror, hand pad and a box to enclose the components and a surface with five pegs on it. The user places his hand - palm facing downwards - on the surface of the device. The five pegs serve as control points for appropriate placement of the right hand of the user. The device is connected to a PC with a GUI application which provides a live visual feedback of the top-view and the side-view of the hand (Figure 3). Each user was requested to put his/her left hand on the hand pad and software that has been
installed on computer will be used to capture the hand image from the device.

3.1.1. Software GUI
Figure 4 below allows each user to put his/her left hand on the hand pad and software that has been installed on computer will be used to capture the hand image from the device. This is done after the user has been authenticated by the user.

Figure 3: Hand geometry sensing device

Figure 4: Software Interface to capture the hand image

3.2. Registration Procedure
Registration in a hand geometry recognition system is the process by which a record or template of the individual’s hand geometry is established. Live scans are compared to this template when a user attempts to access an asset. If the live scan matches the template, the user is given access to that asset.

To register in hand geometric, the candidate's hand is placed palm down on the reader's surface. The placement of the hand is aided by pins that serve as guides to correctly orient the hand and fingers for the camera. The camera then takes an image of the hand and stores it. The unit's internal processor and software convert the image of the hand to a mathematical representation, which is then compressed by an algorithm and stored as the user's template. The template may reside in the biometric unit's internal memory, in a centralized database of users, or on other media, such as on a smart card or a hard disk [6].

Registration process involves one of the following two tasks:
(i) Add a new user to the database;
(ii) Update a current user's feature vector.

During the registration phase, five images of the same hand are taken in succession; the user removes his hand completely from the device before every acquisition. These five images are then used to compute the feature vector of the given hand. Re-computing a feature vector simply involves averaging the individual feature values.

3.3. Verification of Identification
Current hand recognition systems use a one-to-one "verification" process to identify individuals. In a verification process, the individual first identifies themselves as a specific person, usually by typing a password or code into a keypad or by presenting a proximity card or smartcard, etc. Once the individual has informed the system as to who he is supposed to be, he then submits his hand to the biometric reader to be scanned.

This process involves matching a given hand to a person previously enrolled in the system. The software in the system compares this scan with the template that the user has identified as his, with the feature vector stored in the database associated with the claimed identity. If the scan and the template match, the individual will be granted access [1].

Let $F = (f_1; f_2; \cdots; f_d)$ represent the $d$-dimensional feature vector in the database associated with the claimed identity and $Y = (y_1; y_2; \cdots; y_d)$ be the feature vector of the hand whose identity has to be verified. The verification is positive if the distance between $F$ and $Y$ is less than a threshold value [7].

Four distance metrics, absolute, weighted absolute, Euclidean, and weighted Euclidean, corresponding to the following four equations:

$$\sum_{j=1}^{d} |y_j - f_j| < \varepsilon_a$$  \hspace{1cm} (1)

$$\sum_{j=1}^{d} \frac{|y_j - f_j|}{\delta_j} < \varepsilon_{wa}$$  \hspace{1cm} (2)
4. Extracting of hand geometry images features

The hand geometry images can be extracted from a hand image in a single shot at the same time. Unlike other multi-biometrics systems (e.g., face and fingerprint, voice and face, etc.), a user does not have to undergo the inconvenience of passing through multiple sensors [8]. Furthermore, the fraud associated with fake hand, in hand geometry based verification system, can be alleviated with the integration of palm print features.

Hand images of every user are used to automatically extract the hand geometry features. This is achieved by first thresholding the images acquired from the digital camera. The resultant binary image is used to estimate the orientation of hand since in absence of pegs, user does not necessarily align their hand in a preferred direction. The rotated binary image is used to compute hand geometry features.

![Figure 6: Screen shot of scanned hands showing Feature Extraction](image)

Each of the acquired images needs to be aligned in a preferred direction so as to capture the same features for matching. According to [9], the image thresholding operation is used to obtain a binary hand-shape image using back background. Since the image background is stable (black), the threshold value can be computed once and used subsequently for other images. The binarized shape of the hand can be approximated by an ellipse.

The parameters of the best-fitting ellipse, for a given binary hand shape, is computed using the moments [10]. The orientation of the binarized hand image is approximated by the major axis of the ellipse and the required angle of rotation is the difference between normal and the orientation of image. As shown in figure 3, the binarized image is rotated and used for computing the hand geometry features, the estimated orientation of binarized image is also used to rotate gray-level hand image.

![Figure 7: Extraction of two biometric modalities from the hand image, (a) captured image from the digital camera, (b) binarized image and ellipse fitting to compute the orientation (c) binary image after rotation, (d) gray scale image after rotation.](image)

5. Benefits of hand biometric systems

5.1. Ease of Use and Acceptance

Hand geometry recognition systems are easy to use, and with minimal training users can learn the correct placement of their hand onto the platen. One potential drawback of any biometric system is users' attitudes towards them. However, attitudes towards hand geometry scanners are usually positive; people generally do not regard the placing of one's hand on a reader as intrusive. This contrasts with some other forms of biometric identification, which are considered more intrusive and may have a stigma associated with them. For example, a retinal scanner sends an infrared light into the eye, which some people dislike; and some individuals associate the fingerprint scanner with criminal activity.

5.2. Resistant to fraud

Short of casting a model of an individual person's hand, it would be difficult and time consuming to submit a fake sample.

5.3. Template size

Using RSI as the standard bearer of hand scan, a template size of 9 bytes is extremely small, orders of magnitude smaller than most other biometric
technologies. By contrast, hand scan biometrics requires 250 - 1000 bytes and voice scan biometrics commonly require 1500 – 3000 bytes.

5.4. Users Perceptions
As opposed to facial scan or eye-based technologies, which can encounter some resistance, the use of hand geometry is not problematic for the vast majority users. It bears very little of the stigma of other authentication methods.

6. Hand Geometry and Fingerprints
Unlike fingerprints, the human hand isn't unique. One can use finger length, thickness, and curvature for the purposes of verification but not for identification. For some kinds of access control like immigration and border control, invasive biometrics (e.g., fingerprints) may not be desirable as they infringe on privacy. In such situations it is desirable to have a biometric system that is sufficient for verification. As hand geometry is not distinctive, it is the ideal choice.

Furthermore, hand geometry data is easier to collect, with fingerprint collection good frictional skin is required by imaging systems, and with retinal-based recognition systems, special lighting is necessary. Additionally, hand geometry can be easily combined with other biometrics, namely fingerprint. One can envision a system where fingerprints are used for (infrequent) identification and hand geometry is used for (frequent) verification.

People’s hands and fingers are unique -- but not as unique as other traits, like fingerprints or irises. That’s why businesses and schools, rather than high-security facilities, typically use hand and finger geometry readers to authenticate users, not to identify them. Disney theme parks, for example, use finger geometry readers to grant ticket holders admittance to different parts of the park. Some businesses use hand geometry readers in place of timecards. Systems that measure hand and finger geometry use a digital camera and light. To use one, you simply place your hand on a flat surface, aligning your fingers against several pegs to ensure an accurate reading. Then, a camera takes one or more pictures of your hand and the shadow it casts. It uses this information to determine the length, width, thickness and curvature of your hand or fingers. It translates that information into a numerical template.

Hand and finger geometry systems have a few strengths and weaknesses. Since hands and fingers are less distinctive than fingerprints or irises, some people are less likely to feel that the system invades their privacy.

7. Integration of Hand geometric
The image capturing and verification software and hardware for the hand geometry recognition units allow these systems to exist as stand-alone units or to be integrated within a multi-unit system (i.e., units at multiple access points are integrated into one system) see figure 9 below. Applications that require a large number of access points and users can be administered at a central location. Having a centralized database of users eliminates the need to store template information on each individual biometric unit and eliminates the need for individuals to register on each device.

Figure 9: Handkey II iCLASS with Smart Card Technology

The operation of Hand geometry device as a stand-alone unit, allows a large number of templates to be stored in the device’s internal memory, its processing time is saved and it permits the storage of templates on the identification cards. Hand geometry devices can operate in harsh environmental conditions and are therefore suitable for indoor as well as outdoor deployment [11]. They rely on hand shape only and therefore are not dust and scratch sensitive. This feature makes this characteristic suitable for access control in almost every branch, even if physical labor is involved [12].

8. Advantages of Hand Geometry Biometrics
- Simple, relatively easy to use and inexpensive
- Hand geometry data is easier to collect, unlike the fingerprints where a good frictional skin is required by imaging systems, and retinal data where special lighting is required
- Environmental factors, such as, dry weather that causes the drying of the skin is not an issue
• Usually considered less intrusive than fingerprints, retinal, etc
• Does not significantly change after ageing

9. Conclusion
Since hand geometry recognition systems perform a one-to-one verification comparison, false rejection rates are among the lowest of any biometric technology. Sandia National Laboratories has documented Recognition Systems’ hand geometry scanners as having a false rejection rate of 0.1 percent i.e. 1 false rejection in 1000 scans. According to the vendor, a false rejection rate of approximately 0.3 percent (3 in 1000) can be expected for the finger geometry scanner.

Hand geometry recognition systems are fairly resistant to fraud. Because these systems use one-to-one verification comparisons when attempting to match to a template, a would-be intruder would have to be able to submit an authorized person’s identification information, and then submit a model of the user’s hands to the reader, in order to defeat the system. This would be both difficult and time consuming.

References