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A survey of biometric technology based on hand shape

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ABSTRACT

Automated biometric systems have emerged as a more reliable alternative to the traditional personal identification solutions. One of the most popular biometrics is hand shape due to its ease of use, non-intrusiveness and public acceptance. This paper presents a survey of the technology used in hand shape-based biometric systems. We first review the component modules including the algorithms they employ. Next we discuss system taxonomies, performance evaluation methodologies, testing issues and US government evaluations. A summary of the accuracy results reported in the literature is also provided. We next describe some of the commercial hand shape biometric systems as well as some recent successful deployments. Finally, we mention a few limitations of the hand shape biometric and give some directions for future research.

1. Introduction

Automatic human identification has become an important issue in today's global information society. Due to increasing security concerns, a large number of systems currently require positive identification before allowing an individual to use their services. During the last decade, there has been a steady research effort[1] towards providing user-friendly and reliable methodologies for access to facilities, resources, services or computer systems. Biometric systems are already employed in domains that require some sort of user verification. It is generally accepted that physical traits like iris, fingerprints and, as more recently debated, hand shape and palmprints can uniquely define each member of a large population which makes them suitable for large-scale identification (establishing a subject's identity) [10,22,50]. On the other hand, in many small-population applications, because of privacy or limited resources, we only need to verify a person (confirm or deny the person's claimed identity). In these situations, one can also use behavioral traits[2] which have less discriminating power such as voice, face, signature and human–computer interaction (HCI) derived patterns.

Comprehensive reviews have been recently published on fingerprint [31], palmprint [50], face [49] and behavioral HCI [46] biometric technologies. In this paper, we survey the state of the art in hand shape-based biometric technology and complement the information provided in [10,36]. We also describe some of the commercially deployed systems and analyze the practical issues concerning enrollment, training and performance evaluation to consider when designing such systems.

Hand shape biometrics is the ensemble of techniques employed in establishing the identity of a person using person's hand silhouette and/or geometric features (e.g. finger lengths, widths, areas, ratios, etc) derived from it. In the biometric literature, hand shape systems usually include *all* systems using information extracted from a hand silhouette, while hand geometry refers to only those systems which use sparse geometric features. A typical hand shape biometric system uses a camera or scanner-based device to capture the hand image of a person and compares this against the information stored in a database to establish identity. Besides person identification, hand imaging has also been used for deriving statistical models of biological shapes [14] and for guiding gesture-based HCI tasks [43].

As often noted in the literature, hand shape biometrics is attractive due to the following reasons:

1. Hand shape can be captured in a relatively user convenient, non-intrusive manner by using inexpensive sensors [2,25,30].
2. Extracting the hand shape information requires only low resolution images and the user templates can be efficiently stored (nine-byte templates are used by some commercial hand recognition systems [35]).
3. This biometric modality is more acceptable to the public mainly because it lacks criminal connotation [16,24].

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[1] As noted in [10], the number of publications on hand-based biometrics has increased almost exponentially since 1998.

[2] In reality most biometrics are both physical and behavioral to some degree [27].

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4. Additional biometric features such as palmprints and fingerprints can be easily integrated to an existing hand shape-based biometric system [10,25,30].

2. Operation of a hand shape-based biometric system

A hand shape-based biometric system operates according to Fig. 1. In the enrollment stage, hand shape data are acquired from the registered users, feature sets are extracted from the acquired data, and one or multiple templates per individual are computed and stored in a database. In the deployment stage, one snapshot of the user's hand is captured, a feature set is computed and then compared to the templates in the database. Based on the comparison result, the claimed identity is accepted or denied (or a new identity is assigned). The identification system comprises the following modules: the sensor module, the feature extraction module, the matching module, the decision-making module and an optional template adaptation module.

2.1. The sensor module

Starting with Sidlauskas' patent [34], the sensor has usually been a low/medium resolution CCD camera attached (beneath or above) to a platform on which the hand is placed (Fig. 2(a)). Most system setups provide their own illumination rather than rely on the ambient light. A recent study proposed using infrared light for better hand segmentation in an unconstrained, real environment [29]. Some multimodal biometric systems capture the palm surface which includes both the hand shape and palmprints [10,25,30]. Other systems capture the dorsal surface of the hand from which only the hand silhouette can be extracted (see Fig. 2 and [13,20,21,34]). The lateral hand surface can be captured as well on platforms with a side-mounted mirror inclined at 45° to the platform [21,30].

Most commercial systems [4,34,35] and some of the research systems [13,20,21,25,33] include on the platform 4–6 pins to guide the placement of the user's hand. Several researchers noted that the guidance pins deform the hand silhouette and decrease user convenience and proposed pin-less setups [1,2,8,10,40,44,45,47,48,51]. In a few systems, the sensor consisted in a 45–180 dots per inch (DPI) scanner [30,40,47,48] while a 3-D range sensor was employed in [41] to extract finger surface curvature features.

A recent trend in hand-based biometric systems is oriented towards a platform-free, non-contact image acquisition setup which responds to hygiene concerns and is considered more user-friendly [29,41,51]. However, such setups introduce additional variation in the images acquired and require sophisticate illumination (see the camera settings recommended in [29]) and/or image processing techniques in order to properly segment the hand from the background.

2.2. The feature extraction module

In the feature extraction module, a set of discriminating features is computed from a user's raw hand image(s).

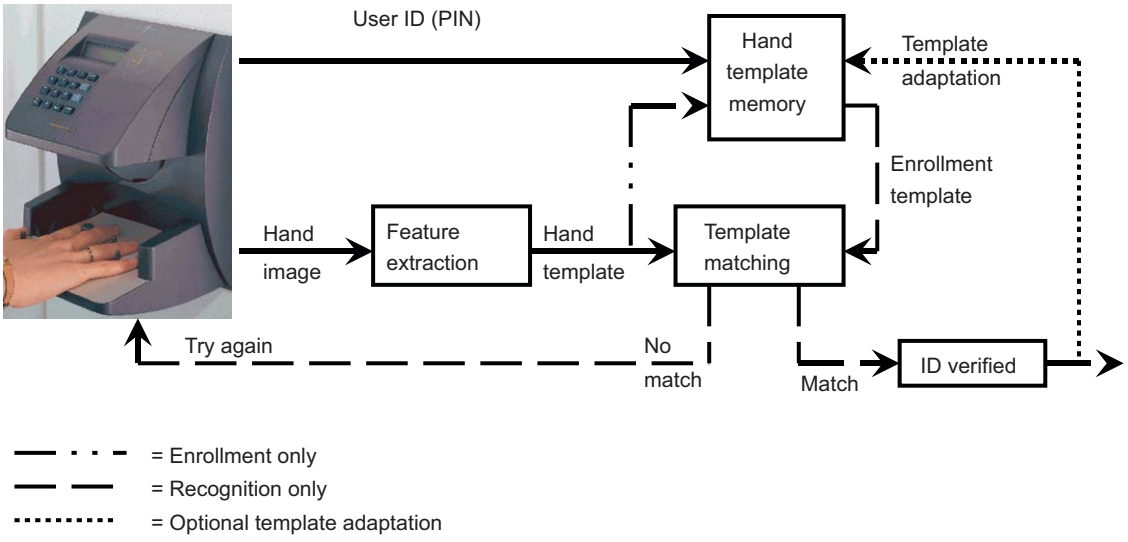

Fig. 1. Processing steps in an identity verification system using hand shape.

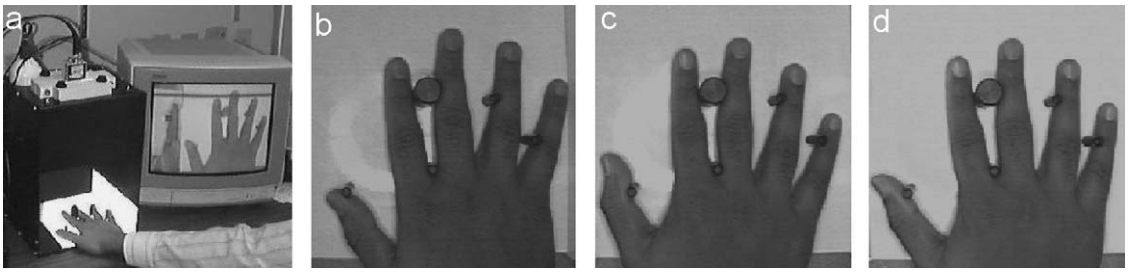

Fig. 2. Example of a hand shape image acquisition system along with three scans of the same hand.