Pattern Recognition 73 (2018) 189–201

Contents lists available at ScienceDirect

Pattern Recognition

journal homepage: www.elsevier.com/locate/patcog

User authorization based on hand geometry without special equipment

Marek Klonowski, Marcin Plata*, Piotr Syga

Department of Computer Science, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, ul. Wybrzeże Wyspiańskiego 27, Wrocław 50-370, Poland

ARTICLE INFO

Article history:
Received 28 December 2016
Revised 26 July 2017
Accepted 15 August 2017
Available online 18 August 2017

Keywords:
Bioidentification
Pattern recognition
Palm scan
Basic devices

ABSTRACT

Bioidentification is one of the most popular methods of user identification, one of the reasons is the fact that the 'access tokens' are part of user's body and cannot be simply lost or forgotten. Recently, the popularity of biometric methods increases even more due to the improved accuracy of measuring devices and lower error rates offered by the algorithms. Despite the technological progress, prices of the top tier equipment remain on a constant, high level. In this paper, we propose a hand geometry user identification algorithm that utilizes data acquired by a standard office scanner, and that has reasonable execution times of both data collection and the identification process. In order to achieve an algorithm that is as accurate as current state of the art algorithms (or even outperforms them) and utilizes only devices that are commonly available in most offices we had to include several non-standard hand geometric features, e.g. the crookedness of the fingers.

Our algorithm was tested on 60 volunteer adults, with age ranging from early 20s to late 50s. The most important results are False Acceptance Rate (FAR) equal to 0.0% and False Rejection Rate (FRR) at the level of 1.19%, with Equal Error Rate (EER) 0.59% during authorization (referred to as *verification mode* since algorithm verifies the claimed identity), when using a template derived from three images. In identification mode we got results FAR=0.0%, FRR=1.19% and ERR=0.59%. We achieved Identification Rate (IR) equal to 100.0% when taking only subjects from the database in identification mode. The subjects were not limited regarding the position of their hand on the scanner, nor were hand injuries and jewelry a disqualifying factor. Moreover, we describe the performance and time needed in a real-life experiments, showing that the algorithm may be used by people without technical background at low cost and is adequate for systems that require medium to high level of security.

1. Introduction

Biometry is one of three main methods of user identification. Nowadays, specific security level must be given to every electronic system, especially if it is a financial platform or a system essential for personal or national security. Biometric characteristics are unique enough across the population to be used in systems that require medium to high security level. Main advantages of biometry are immutability, no necessity of remembering any information nor having any additional tokens by a person who is being verified. Since biometric characteristics are inherent to a person's body, it is nearly impossible to forget or lose them. One of the most popular biometric features used in security systems is finger printing, unfortunately it has several drawbacks. One of them is a requirement for a special device to measure the features. Moreover, people do not accept systems based on finger print due to popular opinion connecting them with police record systems and finger print databases for criminals like AFIS. As an alternative, hand geometry seems to be less effective than "the strongest" biometrics, like finger print [1], yet is widely accepted by the users.

A hand geometry is one of the biometrics that could be used instead of the finger print or other popular biometrics due to high acceptance among the users [1], however this acceptance does not translate into popularity of the biometric systems based on it. In fact, only recently has hand geometry gained considerable attention both in research and commercial use. Exploring this kind of biometry is advisable due to a vast range of features that may be measured and the exact identification, unavailable in other biometrics. What singles out hand geometry among the other bioidentification methods is that there were already attempts of utilizing common devices instead of sophisticated, biometry-dedicated (cf. [2–4]).

* Corresponding author.
E-mail addresses: marek.klonowski@pwr.edu.pl (M. Klonowski), marcin.plata@pwr.edu.pl (M. Plata), piotr.syga@pwr.edu.pl (P. Syga).

http://dx.doi.org/10.1016/j.patcog.2017.08.017
0031-3203/

In our paper, we proposed a very accurate biometric system based on hand geometry, named Hand Geometry and Crookedness Identification Algorithm (HGCIA). We focused on creating a system that can be used without dedicated devices. Moreover, it is robust against errors caused by scanned parts of the clothing and jewelery (like rings or bracelets). Our system works well even if the scanned hand is not clean or has minor cuts or injuries. Capturing hand image is performed by using a simple office scanner. We collected a database that contains from 5 to 10 hand samples of 60 people. Our purpose was capturing hand images in a practical environment, available at low cost in vast majority of the locations that user identification might be needed. We presented an algorithm that identifies 62 hand features based on the distances between some points on a hand contour. We used some of the typical hand geometry features, however we also introduced some new or rarely used features, like distances defining size of a hand, width of the fingers (except the thumb) measured on 3 different heights and crookedness of the fingers. Our method utilizes solely hand geometry method, so that it is faster and does not require any dedicated device, which stands in contrast to methods based on hand geometry supported by some auxiliary biometric features.

In the practical evaluation of our method we achieved False Acceptance Rate (FAR) equal to 0% and False Rejection Rate (FRR) of 1.19% for templates created with 3 sample scans of a hand in verification mode. In identification mode we analyzed also FAR and FRR, where the first rate is interpreted as the fraction of people that where wrongly identified and the second as the fraction of people that were not identified, even though they were enrolled in the database. We got FAR equal to 0% and FRR equal to 1.19%. Additionally, in identification mode we achieved Identification Rate (IR) equal to 100%. IR informs about correctness of subject identification in the database. These results show that our method can be used in systems that require medium to high security level. The achieved results outperform previous identification methods based solely on hand geometry methods and are similar to the best methods based on a palm print or a vascular pattern as an auxiliary system supporting the hand geometry methods, e.g. [4,5] .

1.1. Organization of this paper

The rest of this paper is organized as follows, Section 2 describes related work in biometric identification. In Section 3 we present a description of HGCIA with Section 3.1 focusing on data acquisition. Sections 3.3 and 4 give details on enrollment process and features analysis, respectively. Section 5 discusses our experimental results and time performance. The comparison of our method with known identification systems based on hand geometry is presented in Section 6. Finally, in Section 7 we conclude and indicate some possible future work.

2. Related work

Below we briefly discuss some of the most important previous work related to our research. The idea of extracting hand features in order to identify an individual was published in two patents in 1971 [6,7]. The former was focused on using hand features as an additional, apart from the face image and a signature, biometric security layer of ID cards. The latter patent presented a system for calculating lengths of the fingers.

Authentication based on the properties of a hand was continued in Jain et al. [8], where authors presented method for detecting 16 hand features. A digital camera was used in the paper to take a picture of the hand, which was placed in a *special* platform with pegs. The authors of [8] were the first to prepare a test of the method and show the security of authentication systems of this kind. Test of the system achieved False Acceptance Rate (FAR) equal to 2% and False Rejections Rate (FRR) 15% (first experiment) and FAR = 0%, FRR = 5% (second experiment). In [9], the authors presented a system similar to [8]. Sanchez-Reillo [9] method extracted additional features (increasing total to 25), but the results of their tests were comparable. A novel approach was presented in [10], where authors created peg-free system, achieving FAR = 2.2% and FRR as high as 11.1% in verification mode. The system used a scanner to capture a hand image and calculate widths and lengths of fingers. The authors of [11] introduced additional features that were based on the radius of largest circles that may be inscribed in arbitrary chosen places inside the hand contour. The results of the method were FAR = 1% and FRR = 2% for authentication and FAR = 1% and FRR = 5.5% for identification. In [12] the idea of combining hand geometry features and implicit polynomials to model the fingers and utilizing classifiers based on Mahalanobis distance was presented. They achieved results of FAR = 1% and FRR = 1% for authentication and IR = 95% for identification. The results were followed by Hu et al. [13], that proposed hand shape recognition system based on coherent distance shape contexts that allowed to achieve FAR = 1%, FRR = 0.85% for authentication and IR = 99.60% for identification. Adan et al. [14] presented a system with a special construction for two hands, that allowed to double the count of the features, resulting in FAR = 1.3% and FRR = 1.3% for authentication and IR = 97.60% for identification. The analysis and recognition of hand shape proposed by Xiong et al. [15] allowed to achieve FAR = 1.06% and FRR = 1.95% for identification. The authors of [16] constructed a specially illuminated platform and used Zernike Moments for verification of the hand shape that resulted in FAR = 1% and FRR = 2.42%. The authors in [17] improved the method and got results FAR = 1% and FRR = 0.0% for authentication and IR = 0.99% for identification. In [18] an idea of user's hand representation as weighted undirected complete connected graph was presented. The graph characteristics are represented as features vector comprising novel wavelet energy features of the weighted adjacency matrix of the graph. A test of the method gave results of FAR = 0.69%, FRR = 2.08% and IR = 97.92% for identification. Varchol and Levicky [2] performed an analysis of three methods of comparing features (Euclidean Distance, Hamming Distance and Gaussian Mixture Model). The authors concluded that the best method is GMM with FAR = 0.18% and FRR = 14.58% for authentication. In [19] a system using SVM classifier was described. It achieved IR = 96.53%. In [20] a method based on the back-propagation neural network (BPNN) was proposed and achieved IR = 93.00%. Some of the research on the properties of a hand biometric features were focused on mixed methods. Among others, authors in [4] presented a system where verification process was based on hand geometry and a palmprint. Performed test gave results FAR = 5.29%, FRR = 8.34% (hand geometry method) and FAR = 0%, FRR = 1.41% (hand geometry and palmprint method). Similar mixed methods were presented in [3,21,22]. The paper [23] followed by Park and Kim [5] proposed an identification system based on hand geometry and vascular pattern. The Equal error rate (EER) achieved by these methods were 0.075% (in the former case) and EER = 0.06% (in the latter). However, using vascular pattern requires a special device or a digital camera with infrared capabilities.

Recently, the research on hand geometry identification was rarely published due to lack of serious improvements over previously obtained parameters, however somewhat similar approach has been used in palmprint-based user identification. Zhang et al. [24] presented a method of user authentication utilizing both 2D and 3D features extracted using a dedicated device. In [25], the influence of various light sources used as artificial lighting supporting palmprint acquisition was investigated. In [26], the authors utilized multimodal approach to user identification using hand geometry and a palmprint. The algorithm achieved 99%