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Prediction of values of the dynamic signature features

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ABSTRACT

This paper presents original solutions from the field of intelligent expert systems for use in behavioral biometrics. They combine possibilities offered by biometric methods with the theory of fuzzy sets and the theory of population-based algorithms. Behavioral biometrics is concerned with learned behaviors such as a way of signing, movement, speaking, etc. However, these attributes trend to change over time. This is particularly important in a variety of fields including identity authentication. In this paper we present a new approach to the analysis of changes in behavioral characteristics. The purpose of the proposed approach is to predict values of features describing the so-called dynamic signature. It is the signature represented by waveforms describing a number of features including pen pressure and velocity. The proposed approach can be particularly useful in cases in which the interval between signature acquisition sessions is long. Our approach was tested with the use of the dynamic signature database called ATVS-SLT DB. It seems that the solutions proposed in this paper offer a new and interesting look at the solution of the problem of variability (aging) of biometric features.

1. Introduction

This paper presents original solutions from the field of intelligent expert systems for use in behavioral biometrics. They combine possibilities offered by biometric methods with the theory of fuzzy sets and the theory of population-based algorithms.

In typical issues from the field of biometrics (e.g. identity authentication) biometric attributes are analyzed. They are divided into two categories: (a) physical ones i.e. those related to the construction of the body (e.g. fingerprint, iris, hand shape, face) and (b) behavioral ones i.e. those related to the learned behavior (e.g. a way of signing, movement, speaking, performing specific gestures, typing dynamics, etc.). The signature takes an important place in the group of behavioral characteristics because its acquisition is not controversial and it is socially acceptable. Two main approaches to the signature analysis have been developed: (a) the approach based on the static (off-line) signature, which is represented by a set of geometric features (see e.g. Batista, Granger, & Sabourin, 2012; Bhattacharya, Ghosh, & Biswas, 2013; Kumar, Sharma, & Chanda, 2012) and (b) the approach based on the dynamic (on-line) signature, which is represented by a set of signals describing, for example, pen pressure and velocity (see e.g. Faundez-Zanuy, 2007; Fierrez-Aguilar, Nanni, Lopez-Penalba, Ortega-Garcia, & Maltoni, 2005; Ibrahim et al., 2010; Jeong, Jeong, & Omitaomu, 2011; Kholmatov & Yanikoglu, 2005; Nanni & Lumini, 2006; Nanni, Maiorana, Lumini, & Campisi, 2010).

Dynamics of a signing process is an individual characteristic of the signer, which is difficult to forge and easy to analyze. Dynamic signatures are acquired with the use of graphic tablets or other devices equipped with a touch screen. Recently, many methods for the dynamic signature verification have been developed. In Galbally et al. (2015) the authors present an approach using a fusion of on-line and off-line signatures. The method uses synthetic signatures generated from on-line data. The verification is performed on the basis of synthetic off-line signatures and real on-line signatures. In Liu, Yang, and Yang (2015) the authors propose a novel on-line signature verification technique based on Discrete Cosine Transform and sparse representation. The method creates a compact representation of the dynamic signature, which simplifies the matching procedure. Moreover, the method also extracts energy features. Finally, the energy and sparsity features are used at the verification stage. In Cpałka, Zalasiński, and Rutkowski (2016) the authors have proposed a method using hybrid partitions of the signature, created on the basis of horizontal and vertical sections of the signature. The method uses flexible neuro-fuzzy one-class classifier. In Porwik, Doroz, and Orczyk (2016) the authors have proposed a method using composed features of the signature. The number of features is reduced using

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the Hotelling's approach. The method uses a classifier based on the Probabilistic Neural Network, whose optimal parameters are determined by means of the Particle Swarm Optimization procedure. In Diaz, Fischer, Ferrer, and Plamondon (2017) the authors propose a procedure for training with a single reference signature only. The method duplicates the reference signature a number of times and then the training phase is performed on the basis of the resulting signatures. The duplication scheme is based on a sigma log-normal decomposition of the reference signature. In Sharma and Sundaram (2017) the authors have presented a novel on-line signature verification system based on an extension of the traditional Dynamic Time Warping (DTW) matching scheme. The method uses a set of features derived from a Gaussian Mixture Model for the alignment of the signatures using DTW. In Xia, Chen, Luan, and Song (2017) the authors propose a method of signature alignment based on Gaussian Mixture Model in order to obtain the best matching. In the verification phase a modified Dynamic Time Warping with a signature curve constraint is used, which improves the verification efficiency. Moreover, weight factors are dynamically assigned to features, which depend on the coefficient of variation in order to improve the robustness. In Guru, Manjunatha, Manjunath, and Somashekara (2017) the authors have proposed a method for selection of writer dependent features based on feature relevance. Selected features are represented in the form of an interval valued symbolic feature vector.

In our previous papers we have also proposed a few effective methods for identity verification based on the dynamic signature (see e.g. Cpałka & Zalasiński, 2014; Cpałka, Zalasiński, & Rutkowski, 2014; Zalasiński, 2016; Zalasiński, Cpałka, & Rakus-Andersson, 2016b). They performed biometric features extraction and their analysis using computational intelligence methods. The features then had a different interpretation. They were the so-called global features of the dynamic signature (describing e.g. the total time of a signing process or the number of pen-ups). They were also templates determined in the partitions of the signature (interpreted as templates of the signature dynamics). The proposed methods for extraction, interpretation of biometric behavioral attributes and identity verification were very effective. However, their drawback was a high sensitivity to changing the way of signing, especially when an interval between the moments of signing was significantly long. This problem applies to most biometric features (not only in the dynamic signature) and it is called aging (Galbally, Martinez-Diaz, & Fierez, 2013). It is also independent from an adopted form and interpretation of biometric features extracted from the dynamic signature.

In this paper we propose a new approach to the analysis of changing behavioral biometric features. The purpose of this approach is to predict values of the global features describing the so-called dynamic signature. The novel element of the proposed approach is: (a) the idea of prediction of biometric features values using computational intelligence methods, (b) the use of the flexible fuzzy system for prediction, and (c) the use of population-based algorithms for selecting parameters of the fuzzy system used. The paper has been prepared on the basis of our preliminary research results from the field of prediction of biometric features' values. They were satisfactory and were published in our paper (Zalasiński, Łapa, Cpałka, & Saito, 2017). In that work, we used a basic prediction scheme (in this paper we compare many different variants); a simplified evolutionary algorithm in the phase of updating parameters of the system used for feature prediction (herein we use a newer population-based algorithm); and a basic version of the system used to predict features (in this paper we use many different systems varying, among others, in the number of inputs and fuzzy rules). Moreover, the approach to predicting the variability of dynamic signature features has been preliminarily tested using the dynamic signature verification process. Signature verification has been performed using the method proposed in Zalasiński, Cpałka, and Hayashi (2015). Simulation results have been described in Section 3 (Simulations). In the articles of other authors and our previous articles (especially in Zalasiński et al., 2017) no analogous approach has been considered so far. Characteristic features of our approach in comparison with other methods are presented in Table 1. As shown in Table 1, the method performing prediction of the dynamic signature global features has several unique properties in comparison to other methods using the global approach. A certain disadvantage of the proposed method may be the need to teach the system to predict features. It is implemented for each user independently.

Table 1
Main characteristics of the algorithms for the on-line signature verification based on global features approach (**f1**-Does the method combine global features based approach with regional or local approach? **f2**-Does the method select global features of signature in order to increase accuracy of signature verification? **f3**-Does the method focus on fast performance? **f4**-Does the method evaluate the stability of global features of the signature? **f5**-Does the method take into account a hierarchy of selected global features of the signature in the classification process? **f6**-Is a given way of classification interpretable? **f7**-Does the method use a prediction mechanism of the dynamic signature global features' values?) .

Characteristic of the method	f1	f2	f3	f4	f5	f6	f7
Fierrez-Aguilar et al. (2005)	**yes**	**yes**	no	**yes**	no	no	no
Guru et al. (2017)	no	**yes**	no	**yes**	no	no	no
Nanni and Lumini (2006)	no	no	no	no	no	no	no
Nanni et al. (2010)	**yes**	no	no	no	no	no	no
Zalasiński et al. (2015)	no	**yes**	**yes**	**yes**	**yes**	**yes**	no
Our method	no	no	no	**yes**	**yes**	**yes**	**yes**

The proposed approach can be used in practice in two ways. First, it can be an independent mechanism used to evaluate the biometric features. In this case, it allows us to assess the stability of the biometric features over time. This approach could also be a component of the existing biometric methods (it has been pretested by us, as described in the previous paragraph). Its use can be particularly important if the time interval between successive sessions of the acquisition of biometric features (in particular related to the dynamic signature) is long. In the methods proposed earlier we used weights of the biometric features used in the verification phase (see e.g. Cpałka & Zalasiński, 2014; Cpałka et al., 2014; Cpałka et al., 2016). When selecting weights values we took into account the homogeneity of the features in a single training session (when the user creates several reference signatures) and the heterogeneity within the entire set of features. Having a mechanism for predicting the values of biometric features we can take into account changes of the features over time and on the basis of these changes determination of weight values can be performed. The proposed approach can also be used in the context of other problems from the field of behavioral biometrics.

The structure of the paper is as follows: Section 2 describes the proposed method for predicting values of the dynamic signature global features, Section 3 characterizes obtained simulation results, and Section 4 contains conclusions.

2. Description of the proposed approach

The remarks on the proposed method for predicting values of the dynamic signature global features can be summarized as follows:

- It allows prediction which is realized independently for each user on the basis of the values of features from previous training sessions (Fig. 1). Moreover, the prediction mechanism can be extended by the ability to update the template on the basis of data from the test session concluded with a positive verification of the signature.