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New method for the on-line signature verification based on horizontal partitioning

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ABSTRACT

Verification of identity based on the analysis of dynamic signatures is an important problem of biometrics. The effectiveness of the verification significantly increases when the dynamic characteristics of signature (e.g. velocity of the pen) are considered. These characteristics are individual for each user and difficult to imitate. The effectiveness of the verification can be further improved by using partitioning. In this paper we propose a new method which uses partitioning. In our method partitions represent areas of high and low speed of signature and high and low pen's pressure. All selected partitions are used by our algorithm, but more important in the classification process are these partitions, in which the signatures of the user acquired during training phase are more stable. Moreover, final classification is interpretable. In this paper we present the simulation results of the proposed method for the two databases: SVC2004 and BioSecure Database.

1. Introduction

Biometrics is the science of recognising the identity of a person based on some kind of unique personal attributes. The task of biometrics is verification or identification of a human identity. Nowadays biometric systems are increasingly being used for commercial purposes, for example as the access verification systems to the workplace or as the systems supporting identity authentication in banks. The most commonly known biometric attributes are fingerprint and iris which belong to the physiological attributes group. The second group of biometric attributes are the ones based on behavioural characteristics of human. Verification based on these attributes is more difficult than verification based on the physiological ones, but it has also a lot of advantages. The most important of them is that this process is less invasive than verification with use of the physiological attributes like fingerprint or iris. Of course, some behavioural attributes can also cause controversy. For example identity identification systems using gait as biometric attribute may cause the fear of invigilation. On the other hand, signature is very interesting behavioural attribute which is commonly accepted in the society. This attribute is used in identity verification process.

Signature biometric attribute may be classified into two categories – static (off-line) signature and dynamic (on-line) signature. Off-line signature contains only information about the shape of the signature. It can be used for example in verification of signatures from the documents. On-line signature contains also information about dynamic features changing during signing process, e.g. velocity, acceleration and pressure. In this case the shape of the signature is represented by the horizontal and vertical trajectories. Thanks to the features which describe dynamics of signing, signature verification based on the on-line signature is more reliable than verification using the off-line signature. The dynamic features make the signature more unique and more characteristic for the individual.

Identity verification based on biometric attributes is also very interesting from the practical point of view. For example, if efficiency of identity verification based on dynamic signature is high enough, this behavioural attribute might replace many commonly used methods of authorization, e.g. password authorization, PIN code authorization. Disadvantage of these traditional methods is possibility of forgetting or losing password or PIN code, which may be very dangerous. The use of dynamic signature in authorization process eliminates these dangers.

Identity verification methods presented in the literature may be categorised into few groups:

- *Global feature based methods*: Some methods based on the global features which are extracted from signature and used during training and classification phase. Examples of these

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features are signature total duration and number of pen-ups. Approach based on global features may be found in many research papers. In [1] authors have proposed method of signature verification based on the ensemble of the Parzen window classifiers. In [2] system based on the two-class problem is presented. The system uses the Support Vector Machine to classify vector of signature global features as genuine or forgery. In [3] the method using combination of two-class classifier and one-class classifier is proposed. Fusion of the classifiers is realised using the radial basis function-support vector machine. In [4] the algorithm for building an ensemble of on-line signature verification systems based on one-class classifiers and using "artificial features" is shown. These features are extracted using so-called OverComplete global feature combination, and a small subset of features used during classification is selected by sequential forward floating selection. In [5] authors have proposed a set of features sorted by their individual discriminative power for the group of signers. The best results give fusion of classifiers based on the Principal Component Analysis method and the Parzen window classifier.

- *Function based methods*: Another approach commonly used in identity verification based on dynamic signature is function-based approach. This approach bases on comparison of time functions, which contains information about changes of signature features over time. Time functions extracted from the signature are compared to the time functions of the other signature and classification is made on the basis of this process result. Comparison is performed using elastic distance measures, e.g. the Dynamic Time Warping (see [6]). In this approach one can use time functions acquired during the signing process on the digital tablet (e.g. x-trajectory, y-trajectory, pressure), their derivatives (velocity, altitude) or combinations (difference between the values of two consecutive points of x-trajectory or y-trajectory). In [7] authors have proposed verification based on the set of features computed for each discretization point. This set contains features which describe shape of the signature and the ones based on dynamics of the signing process. In [8] classification based on the distances of the test signature to the nearest, farthest and template reference signatures, stored in a three-dimensional feature vector, was presented. The distances are computed by the Dynamic Time Warping algorithm and the feature vector is classified into one of the two classes (genuine or forgery) by classifier based on the Principal Component Analysis. In [9] classification by combination of vector quantization and the Dynamic Time Warping was presented. The combination is performed by means of score fusion. In [10] dynamic signature verification system based on the Linear Programming Descriptor classifier was presented. In this method the time functions extracted from the signatures are transformed by the Discrete 1-D Wavelet Transform and next the Discrete Cosine Transform is used to reduce the approximation coefficients vector to a feature vector of a given dimension.
- *Regional based methods*: The literature contains also approaches relying on segmentation of signature into some regions, which are used during training and verification phase. Methods based on regional information of signature often use classifier based on the Hidden Markov Models (see e.g. [11]). Many authors propose also different methods of classification. In [12] signatures are segmented into strokes and for each of them reliability measure is computed on the basis of the features values which belong to the current stroke. In [13] a stroke-based algorithm that splits velocity signal into three bands was proposed. This approach assumes that low and high-velocity bands of the signal are unstable, whereas the medium-velocity band is useable for discrimination purposes.
- *Hybrid methods*: In the literature one can also find the hybrid methods which are based on combination of the described approaches. For example in [14] system for dynamic signature verification based on an ensemble of local, regional, and global matchers was presented. The system uses fusion of two methods employing the Dynamic Time Warping, the Hidden Markov Model approach and the Linear Programming Descriptor classifier trained by global features.

In this paper we propose new method for the on-line signature verification based on partitioning. The method belongs to the regional based methods group and it bases on partitioning of waveforms which describe the signature. The idea of partitioning has been considered in the literature:

- In [15] authors have proposed very interesting and effective algorithm. It assumes using in the classification process vertical and horizontal trajectories of signature which lies in the regions of the signature extracted on the basis of the values of pressure and velocity signals. The regions of signature are called partitions. After division of signature trajectories into partitions, the template which represents information about the signer is created for each partition on the basis of the training signatures. Next, selection of the most discriminative partition (called stable partition) is performed. Stable partition is selected on the basis of similarities between each training signature of the user and the template. The template from selected partition is used during verification process to determine whether the test signature of the user is true or not.
- In [16] authors have proposed effective method for dynamic signature verification using multi-section vector quantization. The method is based on the multi-section codebook approach. In this approach training signatures are split into several sections. The codebooks are generated individually for each user and for each part of the signature. Final decision is taken by combining individual contributions of each section by simple averaging.
- In [17] authors have proposed fast method for dynamic signature verification, which uses vector quantization algorithm with time modelling. The method also uses multi-section codebook modelling and extends the feature set of the time step value, what in effect improves the classification results. In this paper authors have also tested many approaches to multi-section distance fusion.
- In [18] authors have proposed original algorithm to signature trajectories partitioning, based on selection of the discretization points. In this method partitions correspond to the moments of time. The moments of time correspond to specific moments of creation of the dynamic signature. For all partitions are determined weights of importance used in the classification of signatures.
- In [19] authors have proposed algorithm based on vertical partitioning which uses all partitions to identity verification, but classification in the algorithm is performed on the basis of the so-called weighted t-norm (see [20]), what would not allow the interpretation of the classifier work.

Our method is characterised by important advantages over other methods available in the literature which use partitioning of dynamic signature. These advantages include, among others, use of the partition importance in the classification process of dynamic signature, interpretability of knowledge acquired in the classifier of the signature and use of the abilities of fuzzy systems in the signature classification. The authors of this paper have developed a new class of neuro-fuzzy systems – flexible neuro-fuzzy systems and their previous work proven that these systems work with very