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A novel video-based system for in-air signature verification

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ABSTRACT

At present, the common online signature verification systems adopt the contacted model of signing on a tablet or a phone screen, which have a great dependence on the device. Considering that the development of biometrics tends to the long distance and non-contact mode, a novel video-based system for in-air signature verification is proposed. First, the fingertip tracking is used for generating unique signature trajectory from the in-air signing videos. In combination of contrapuntally improved dynamic time warping (DTW) method, the Fast Fourier Transform (FFT) and the analysis on the signature length, a Gaussian distribution-based fusion algorithm is proposed for in-air signature verification. Finally, comprehensive experiments are conducted on a self-built database consisting of 560 signatures, then a false rejection rate (FRR) of 2.86% and a false acceptance rate (FAR) of 1.90% are achieved with an average matching time of only 24 ms, which have demonstrated the effectiveness of our proposed system.

1. Introduction

With the advent of the information age, the information revolution made a huge impact on the traditional work and life styles. In view of the critical role of identity authentication in the online payment and settlement, the information security has been suffering severely test and the electronic identity authentication has become an important part of the information age. Meanwhile, with the great progress of biometric authentication technology, biometrics as an authentication password has gradually attains to the requirements of automated, real-time and accurate, thus it has attracted the widespread attention in the domain of pattern recognition. Commonly used biometrics includes fingerprint, face, voice, signature, gait, vein etc. As ancient and generally accepted biological characteristics among them, signature has been widely studied and applied to many occasions which need identity authentication.

In general, signature verification can be divided into off-line (static) and online (dynamic) signature verification. Off-line signature verification is a technique for the identification of 2-D signature images written on a document, which only consists of the shape information. While online signature verification technology is based on the dynamic features in signing on the digital tablet or PAD, such as coordinates and pen pressure at each point along the signature trajectory [1], which makes the online signatures more distinct and robust, as well as more difficult to be forged because of the diversity of the features and the integrity of the signature information.

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The overall process of online signature verification includes data acquisition, preprocessing, feature extraction and matching. Among them, feature extraction plays a very important role and existed strategies can be divided into two categories, parameter-based and function-based. The advantage of the former is more reliable, easier access features with smaller size and less computation. The most commonly used parameters include the position, velocity, acceleration, pen strokes etc. [2]. While function-based features utilize timing signals to describe the signatures, such as orbit, angular velocity, pressure and orientation, which are considered to be more capable to reflect the content of the signature [3]. It has been demonstrated that speeds on *X*-coordinates and *Y*-coordinates are the most efficient features by close observation and analysis on stability observation [4]. Parodi et al. obtained the optimal feature combination by the consistency factor [5]. Recently, Fayyaz, et al. also achieved good performance by utilizing a sparsity autoencoder to train features from signatures [6].

As for matching process, most of the classic pattern recognition algorithms have been adopted for signature verification [7]. Among them, the dynamic time warping algorithm (DTW) is the most popular scheme [8], and shows its superiority on similarity measurement when the length of the two samples are not matched. To further increase the accuracy, a team from Turkey Sabanci University improved the principal component analysis (PCA) based on DTW method in *First International Signature Verification Competition* (SVC2004), which achieved the best performance with 2.84% and 2.89% EER in task 1 and task 2 [9,10]. Meanwhile, there are some studies on improving the DTW performance by selecting special points to narrow the area of dynamic warping [11]. In addition, other methods such as Hidden Markov Model (HMM) [12], Support Vector Machine (SVM) [13], Fourier Transform (FT) [14], Neural Network (NN) [15], have also been successfully applied for the signature authentication system.

The above researches are mainly based on the 2-D signature information, which is obtained from the plane only. With customers' increasing demands for usability, flexibility, friendliness and security, 2-D signature is gradually beginning to reveal its deficiencies, especially its security will face significant challenges with emergency of automatic signature machine (autopen). Aimed to the above problems, 3-D non-contact authentication method appears and attracts more attention for its non-imitativeness and friendliness. But the data acquisition of signature trajectory in 3-D space is far more difficult than that on 2-D digital tablet, which makes it becomes the most challenging part for the in-air online signature verification.

In 3-D data acquisition for signature verification, high speed cameras and hand held devices were firstly introduced, and the result of 3.5% FAR with 3.6% FRR was obtained in the 96 sets of data, by means of the commercial signature authentication engine from *JAPAN CyberSIGN* company [16]. Next, the infrared and RGB cameras were also utilized to get the 3-D trajectory of signature, by combining with the hand shape features to recognize the English words from A to J, it achieved the result of 2% FAR when FRR is zero [17]. Recently, the smart phone's acceleration sensor is explored to obtain 3-D trajectory of in-air signature, by converting it to the 2-D signature data and then using SVM as a classifier, the paper achieved EER of 0.8% in the self-built database [18]. In addition, since the sign's gesture is changing with time, a template updating algorithm was proposed to improve the system performance with finally 4% EER [19]. After comparing with HMM, Bayes classifier, DTW and other algorithms for the in-air signature authentication, Bailador et al. demonstrated that the DTW algorithm achieves the best performance [20]. As a new wearable device, the Google glasses were used to track finger trajectories in the first person vision and the signature verification was conducted by the DTW algorithm successfully [21].

Although the in-air signature has drawn more attention in recent years, the research is still at a beginning stage. And most research work relies on mobile phones or tablet, as well as other external handheld devices for data acquisition and system communication. Aiming at the low cost, low equipment dependence for practical in-air online signature verification system, we put forward a novel authentication mode for non-contact video-based finger signature action. The main contributions of this paper are as follows: a) Develop a novel video-base in-air signature verification mode; b) Propose an improved DTW algorithm based on the characteristic of in-air signature; c) Demonstrate the validity of FFT algorithm in the verification of continuous track signature; d) Design a DTW-FFT fusion algorithm based on Gaussian probability distribution.

The rest of this paper is organized as follows. Section II describes our proposed method in detail. Section III shows experiments and analysis on the results. Finally, we discuss the conclusions and future work in section IV.

2. Method

The implementation framework of video-based in-air signature verification system is similar to that of common online signature verification system, both of them include registration and verification steps. However, because this paper aims at the in-air signature trajectory acquired through video analysis, so the steps of data acquisition and pre-processing are totally different from that of online signature verification system. What's more, we also design a new feature extraction and matching method, especially for in-air signature. The overall block diagram of the system is shown in Fig 1. In the training stage, users sign in the air five times facing the high-speed camera. Next, the improved Tracking Learning Detection (TLD) algorithm is used to track the finger trace of in-air signature, and then generate the signature trajectory and form the user registration samples after the targeted pre-processing. Finally, the reference samples are calculated by the DTW-FFT fusion algorithm, in order to form the user template and obtain the threshold. In the test stage, the improved TLD algorithm and pre-processing method are also used to obtain the trajectory of the test users. Then use the same algorithm to compute the similarity with template and make the decision based on the comparison results.