

Non-English and Non-Latin Signature Verification Systems: A Survey

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Abstract - Signatures continue to be an important biometric because they remain widely used as a means of personal verification and therefore an automatic verification system is needed. Manual signature-based authentication of a large number of documents is a difficult and time consuming task. Consequently for many years, in the field of protected communication and financial applications, we have observed an explosive growth in biometric personal authentication systems that are closely connected with measurable unique physical characteristics (e.g. hand geometry, iris scan, finger prints or DNA) or behavioural features. Substantial research has been undertaken in the field of signature verification involving English signatures, but to the best of our knowledge, very few works have considered non-English signatures such as Chinese, Japanese, Arabic etc. In order to convey the state-of-the-art in the field to researchers, in this paper we present a survey of non-English and non-Latin signature verification systems.

Key Words: *Off-line and On-line signature verification, Biometrics, Authentication systems, Forgeries.*

I. INTRODUCTION

The handwritten signature has always been one of the most simple and accepted ways to authenticate an official document. Research into signature verification has been vigorously pursued for a number of years and it is being explored especially in the off-line mode [1, 2]. The recognition of human signatures is significantly concerned with the improvement of the interface between human-beings and computers [3, 4]. A signature verification system and the associated techniques used to solve the inherent problems of authentication can be divided into two classes: (a) on-line methods [7, 8] to measure the sequential data such as order of stroke, and writing speed, pen pressure and other temporal information by utilizing intelligent algorithms [9, 10], and (b) off-line methods [11, 12] that use an optical scanner to obtain handwriting data written on paper. On-line signature verification has been shown to achieve much higher verification rates than off-line verification [11] as a considerable amount of dynamic information is lost in the off-line mode.

Signatures are not considered as a collection of letters and words [14]. It is often difficult for a human to instantly verify two signatures of the same person because signature samples from the same person are similar but not identical and signatures can change depending on elements such as mood, fatigue, time etc. Great inconsistency can even be observed in signatures according to country, habits, psychological or mental state, physical and practical conditions [15]. Significant research has been performed in the field of signature verification involving English signatures, but to the

best of our knowledge, very little attention has been given towards non-English signatures such as Chinese, Japanese, Arabic etc. In order to convey the state-of-the-art of non-English signature verification, in this paper we present a survey of non-English and non-Latin signature verification systems.

II. SIGNATURE VERIFICATION CONCEPT

In general to deal with the problem of off-line/on-line signature verification, researchers have investigated a commonly used approach which is based on two different patterns of classes: class1 and class 2. Here class1 represents the genuine signature set, and class2 represents the forged signature set.

Usually two types of errors are considered in signature verification system. The False Rejection, which is called a Type-1 error and the False Acceptance, which is called a Type-2 error. So there are two common types of error rates: False Rejection Rate (FRR) which is the percentage of genuine signatures treated as forgeries, and False Acceptance Rate (FAR) which is the percentage of forged signatures treated as genuine.

III. TYPES OF FORGERIES

There are usually three different types of forgeries to take into account. According to Coetzer et al. [16], the three basic types of forged signatures are indicated below:

1. Random forgery. The forger has no access to the genuine signature (not even the author's name) and reproduces a random one.
2. Simple forgery. The forger knows the author's name, but has no access to a sample of the signature.
3. Skilled forgery. The forger has access to one or more samples of the genuine signature and is able to reproduce it.

But based on the various skilled levels of forgeries, it can also be divided into six different subsets. The paper [17] shows various skill levels of forgeries and these are shown below.

1. A forged signature can be another person's genuine signature. Justino et al. [18] categorized this type of forgery as a Random Forgery.
2. A forged signature is produced with the knowledge about the genuine writer's name only. Hanmandlu et al. [19] categorized this type as a Random Forgery whereas Justino et al. [18] categorized this type as a Simple Forgery. Weiping et al. categorized this type as a Casual Forgery [20].
3. A forged signature imitating a genuine signature's model reasonably well is categorized as a Simulated Forgery by Justino et al. [18].

4. Signatures produced by inexperienced forgers without the knowledge of their spelling after having observed the genuine specimens closely for some time are categorized as Unskilled Forgeries by Hanmandlu et al. [19].

5. Signatures produced by forgers after unrestricted practice by non-professional forgers are categorized as Simple Forgery/Simulated Simple Forgery by Ferrer et al. [21], and a Targeted Forgery by Huang and Yan [22].

6. Forgeries which are produced by a professional imposter or person who has experience in copying Signatures are categorized as Skilled Forgeries by Hanmandlu et al. [19].

IV. NON-ENGLISH SIGNATURE VERIFICATION TECHNIQUES

We think that the shape of non-English signatures and writing styles are different to English signatures. Arabic script is written from left to right. Most of the Japanese signatures consist of two to six kanji, hiragana and/or katakana component characters and they are spaced appropriately from each other. Persian signatures are also different from other signature types because people usually do not use text in it and they draw a shape as their signature. Hence in this work, non-English signature verification systems are reported and they are described below.

A. Chinese Signature Verification Systems

Chinese signature consists of many strokes and these strokes can be taken into consideration for signature authentication. Liu [23] discussed this issue, but he discussed it from the point of view of identifying a signature manually.

Off-line Chinese Signature Verification Systems

Lv et al. [24] developed a Chinese off-line signature verification system. A database of 1100 signatures was developed for experimentation. Support Vector Machines (SVM) are used as a classifier. Four different types of features such as moment feature, direction feature, grey distribution and stroke width distribution are used here. Based on each feature, the accuracies are calculated separately and an average accuracy was also calculated based on all combined feature sets. An average error rate 5.10% is found using the combined feature sets. SVM based techniques are also proposed by Chen et al. [25] and Meng et al. [26] for Chinese signature verification. Shen et al. [27] proposed an off-line Chinese signature verification system based on geometric features. A database of 800 signatures was used for experimentation and obtained 96.8% accuracy. Four main features such as: (a) Envelope of the signature (b) Cross-count feature (c) Centre of gravity feature and distance between vectors made from the centre of gravity (d) Embedded white area and position are used to optimise the verification scheme. Some similar works are also proposed by Bajaj et al. [28] and Huang et al. [29].

Lin and Li [30] proposed a Chinese signature verification scheme using normalized Zernike moment invariants (NZMI). A total of 210 signature samples were collected from 35 writers. The average accuracies of 8% and 12% are obtained for FRR and FAR, respectively. Belkasim et al. [31] introduced a new recursive formula to derive Zernike moments.

In another work of Lin and Li [32], they utilized a set of shape features based on special characteristics of Chinese signatures along with high pressure feature. Their features includes: (a) Ratio of a signature's height to its width. (b) Ratio of a signature's height to its packed width (c) Slant (d) Stroke width. To define the global high-pressure features (GHP) they use Ammar et al's [33] dynamic threshold selecting method. A database of 100 genuine Chinese signatures and 50 forged signatures are collected for the experiment. Reported FRR and FAR rates are 1.0% and 4.0%, respectively.

Chang et al. [34] presented a dynamic handwritten Chinese signature verification system based upon a Bayesian neural network. Features such as: timing features, average velocity feature, average length in the eight directions, width/height ratio, left-part/right-part density ratio, upper-part/lower-part density ratio etc are utilize in the work. Similar works are proposed by Brault and Plamondon [35] and Lorette [36]. A database of 1200 signature samples is collected. The experimental results show the type I error is about 2% and the type II error rates are approximately 0.1% and 2.5% for "simple" and "skilled" forgeries, respectively.

Ji et al. [37] developed an off-line Chinese signature verification system based on a weighting factor of similarity computation. Their earlier paper introduces an improved approach to verify off-line Chinese signatures and it is described in [38]. In their proposed scheme, seven features such as (a) Relative horizontal centre (b) Relative vertical centre (c) The number of points having horizontal neighbours (d) The number of points having vertical neighbours, (e) The number of points having positive diagonal neighbours (f) The number of points having negative diagonal neighbours and (g) Stroke thickness of the segments are used. This technique for off-line Chinese signature verification based on different weighting factors is compared with an expert on questioned documents used to verify a signature sample [39]. The experimental results are generated differently using different data sets. The average ERR is 3.30% and the average EAR is 16.50% for simple forgeries when the weighting factor is 0.04.

Ji and Chen [40] proposed an off-line Chinese signature verification System. A method to solve the problem for random forgeries and simple forgeries is presented in their paper. The pre-processing techniques used here are described in detail in [41]. The features are extracted in seven steps as discussed in the paper [33]. A database of 4800 handwriting samples from 32 participants is used in this method to obtain a verification accuracy rate of 91%.

Zuo et al. [42] proposed an off-line Chinese signature verification scheme using Pseudo-Zernike invariant moments as for static features due to scale and translation invariance. High-density factors, relative gravity centre and Wavelet Transform are used as dynamic features. A database of 290 signatures was collected. As a result of their experiments, the FAR and FRR was 7.84% and 6.89%, respectively.

Cheng et al. [43] presented a handwritten Chinese signature verification scheme. An attributed string matching approach based on the writing sequences of an input signature is proposed. In order to obtain an attributed string

that is used in the string matching similarity calculation, the input signatures are split into several segments. The stroke attributed feature is used in their proposed technique. A large database is used to obtain 1.5% and 3.6% for type1 and type2 error rates respectively. A similar matching method is performed by Chen et al. [44].

Ye et al. [45] developed an off-line handwritten Chinese signature verifier with an inflection feature. Different scale wavelet transforms are used in the curvature signature signals transformation. The signature curves are divided into several parts, i.e. the strokes, according to the inflections. The distance between two corresponding strokes is measured with a Dynamic Time Warping algorithm. A database of 3120 signatures was collected for the experiments. The rate of FRR and FAR (skilled forgery) are 1.33 % and 6.72%, respectively.

On-Line Chinese Signature Verification Systems

Xiao and Dai [46] introduced a hierarchical on-line Chinese signature verification system. First, global features are applied to obtain a statistical decision through comparing their weighted distance. Secondly, the input primitive string is matched with its reference primitive string by attributed automaton. In their paper an attributed automaton [47] which has four edit operations (insertion, deletion etc.) are applied to solve the problem of inconsistency of signature segmentation.

Tseng and Huang [48] presented an on-line Chinese signature verification scheme based on the ART Neural Network. The verification method based on one bit quantized pressure patterns, which constitute time domain information. The timing information contained in the on/off motions of handwriting is analysed by Zimmermann and Varady [49]. Carpenter and Grossberg [50] also proposed a method based on the ART Neural Network. The error rates 4.5% and 5% are obtained for type1 and type 2, respectively. Techniques based on neural network expert systems to identify Chinese signature are proposed by Ng and He [51] and He et al. [52].

Cheng et al. [53] presented an on-line Chinese signature verification system using a voting scheme. Global feature, line segment feature, 8-directional chain code feature, Spectral information, similarity of position sequences, similarity of velocity sequence, similarity of attribute strings, segment correlation, Tremor feature are used in these nine expert steps. A database of 600 genuine signatures and 12000 forge signatures is used. Some similar types of works are conducted by Suen et al. [54] and Jeng et al. [55] based on neural networks and wavelet transforms respectively. Y. Mizukami [56] developed a handwritten Chinese character recognition system using hierarchical displacement extraction based on directional features. Other techniques involving on-line signature verification can be obtained in [57-64].

B. Japanese Signature Verification Systems

The Japanese handwritten signature verification is difficult due to the lack of stability and individuality. Only a few articles are available on Japanese handwritten verification and they are discussed as follows. Ueda et al. [65] presented an off-line Japanese signature verification system using a pattern matching technique. The similarity

between two signatures obtained by pattern matching is affected by stroke widths. Stroke widths vary with the pen used for signing, and even if signatures are written with the same pen, the stroke width may also vary. In their modified pattern matching method, the strokes of the signatures are first thinned and then the thinned signatures are blurred by a fixed point-spread function. A database of 2000 signatures including 100 genuine signatures from 10 writers and 100 forged signatures from 10 writers are used. An average error rate 9.10% is obtained. Some techniques for verification of Japanese handwritten signatures have been proposed in [66-68].

Yoshimura and Yoshimura [69] presented off-line verification of Japanese signatures after elimination of background patterns. Some preprocessing techniques to eliminate the background pattern are performed as follows: position adjustment, filtering, clipping of random noise and smoothing for noise elimination etc. The verification stage following the preprocessing stage is based on the Arc Pattern Method. A small data set is used to obtain an error rate of approximately 14%. Mizukami et al. [70] proposed an off-line Japanese signature verification system using an extracted displacement function.

C. Persian Signature Verification Systems

Ghandali et al. [71] proposed an off-line Persian signature identification and verification system based on Discrete Wavelet Transform and image fusion. In this method, DWT is employed to access high-frequency bands of signature shape. Then, different samples of a person's signature are fused together based on high frequency bands to generate the signature patterns. This pattern is saved in the learning phase. SVMs are used here as classifiers. A database consists of 6 genuine, 1 simple forgery and 1 skilled forgery signatures from each of the 90 signers is used. The error rates, 8.9% and 10% are obtained for FRR and FAR, respectively. Chalechale and Mertins [72], Chalechale et al. [73] proposed a Persian signature recognition system using line segment distribution. Zoghi et al. [74] introduced a Persian signature verification system using Improved Dynamic Time Warping-based Segmentation and Multivariate Autoregressive Modelling. A database including 1250 genuine signatures and 750 forged signatures was used to obtain an accuracy of 88.8% for the testing of skilled forgery signatures. The statistical spectral estimate for each signature segment is obtained via the use of an Auto-Regressive model [75]. The verification process is carried out using an Artificial Neural Network with a multilayer perceptron architecture described in [76].

D. Arabic Signature Verification Systems

Ismail et al. [77] proposed an off-line Arabic signature recognition and verification technique. In the first phase (Identification phase) some features are extracted and there features are: area filtering, translation, extraction of the circularity feature, normalization, image enhancement, partial histogram (Vertical projection, Horizontal projection), Centres of gravity, extraction of the global baseline (BSL), extraction of the upper limit (UL) and lower limit (LL), thinning, calculation of the global slant etc. In this phase, the

features are classified into two main groups: global features and local features. In the second phase (Verification phase) some other features are also extracted such as central line features, corner line features, central circle features, corner curve features and critical point features. A set of signature data consisting of 220 genuine samples and 110 forged samples is used for experimentation. Their system obtained a 95.0% recognition rate and a 98% verification rate. Other techniques of Arabic handwritten word recognition systems are described in [78-87].

V. OUR INSIGHTS AND FUTURE WORK

As we could observe among the literature of non-English signature verification research, the maximum work has been performed for Chinese language systems. For Japanese, Arabic and Persian only a few pieces of work have been done. Despite the many works in this area, from this survey, we can observe that there are still many challenges in this research area. Signatures may be written in different languages and we need to undertake a systematic study of this. To the best of our knowledge there is no published work on signatures written in Indian languages. India is a multi-lingual and multi-script country and except for English, many people write signatures in local state languages such as Hindi, Bangla, Telugu, Tamil, etc. Thus there is a need to work on signatures written in Indian languages. Researchers have used different features for signature verification. Combinations of different classifiers as well as novel and hybrid classifiers should be explored in future work to enhance performance. Accordingly in this survey we noted that all the published work is based on foreground information. A combination of background and foreground information may be considered for obtaining better results in the future.

VI. CONCLUSION

To highlight the state-of-the-art to researchers in the field, this paper presents a survey of the literature on non-English and non-Latin signature verification. Different existing approaches are discussed and compared along with their FAR, FRR and associated accuracies. The accuracy rates obtained so far from the available systems is not sufficiently high, and more research on off-line signature verification as well as on-line signature verification is required.

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