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Online Signature Verification Using Angular Transformation for e-Commerce Services

Peerapong Uthansakul and Monthippa Uthansakul

***Abstract*—**The rapid growth of e-Commerce services is significantly observed in the past decade. However, the method to verify the authenticated users still widely depends on numeric approaches. A new search on other verification methods suitable for online e-Commerce is an interesting issue. In this paper, a new online signature-verification method using angular transformation is presented. Delay shifts existing in online signatures are estimated by the estimation method relying on angle representation. In the proposed signature-verification algorithm, all components of input signature are extracted by considering the discontinuous break points on the stream of angular values. Then the estimated delay shift is captured by comparing with the selected reference signature and the error matching can be computed as a main feature used for verifying process. The threshold offsets are calculated by two types of error characteristics of the signature verification problem, False Rejection Rate (FRR) and False Acceptance Rate (FAR). The level of these two error rates depends on the decision threshold chosen whose value is such as to realize the Equal Error Rate (EER; FAR = FRR). The experimental results show that through the simple programming, employed on Internet for demonstrating e-Commerce services, the proposed method can provide 95.39% correct verifications and 7% better than DP matching based signature-verification method. In addition, the signature verification with extracting components provides more reliable results than using a whole decision making.

***Keywords*—**Online signature verification, e-Commerce services, Angular transformation.

I. Introduction

RECENTLY, the growth of purchasing merchandises via electronic online services so-called e-Commerce has been rapidly driven by huge user demand. However, the technology of user authorization is still based on numeric or alphabet methods such as credit cards, user name and password. These methods are simple to implement but along with ease of frauds. There is an increasing interest in reliable identity verification. Several biometric features have been studied and proved useful, including signature, fingerprint, face, speech, iris, and retina pattern [1]-[2]. These biometric features have advantages over conventional keys or personal identification numbers (PINs) and passwords in that they are free from carriage and memorization problems. However, because most biological characteristics are unchangeable, a more serious problem arises when they are duplicated. Hence, one will hesitate to use the disclosed biological features. The online signature is more robust to the copy problem than other biological features in that it has dynamic characteristics in addition to the morphological characteristics while the others generally provide only the morphological characteristics [3]-[5]. As one can expect, it is very difficult to construct a similarly shaped signature that also contains dynamic features simultaneously. Moreover, one can change his or her signature intentionally in case of security leakage. Because of the dynamic characteristics of online signatures, identical parts of signatures appear at different times. Then there exist delay shifts in signature. In the parametric approaches, they used global features that are not greatly affected by the nonlinear delay shifts [6]. Using only global features has the advantage of being very fast, but the error rates are generally high.

The functional approaches represent the signature signal as a function of time and compare the similarity by accumulating the difference between two functions in time. The delay relationship between two functions is established by the dynamic programming (DP) matching method [7] or hidden Markov Models (HMMs) [8]-[11]. In the DP matching methods, they tried to find the exact matching points between signatures by means of searching which resulted in too much computation. In the HMM methods, much effort was spent on selecting the type of Markov models, and much computation power was used in enrollment procedures for training the models. Recently, to get higher security, hybrid approaches that use more than one kind of feature have been researched [12]. While they acquire very low error rates, the processing time seems to increase.

In this paper, we propose a new method for extracting signature components by considering angle representation in time. This method splits a global delay shifts into many delay shifts for each component. Therefore, it reduces error rate acquisitions when combining verification results of all components. The other advantage of angular transformation is that it reduces the data size of transmission on Internet connection because only angle characteristics are sent from client to server instead of both vertical and horizontal characteristics. In the proposed method, the estimated delay is captured by comparing with the selected reference signature and the error matching can be computed as a main feature used for verifying process. The threshold offsets are calculated by two types of error characteristics of the signature verification

The authors are with the School of Telecommunication Engineering, Suranaree University of Technology, Nakhon Ratchasima, Thailand 30000 (corresponding author phone: 66-44-224351; fax: 66-44-224603; e-mail: uthansakul@sut.ac.th).

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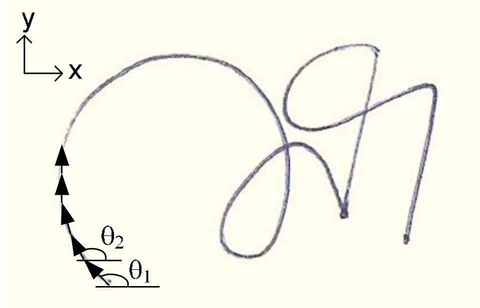

Fig. 1 Demonstration of angular transformation

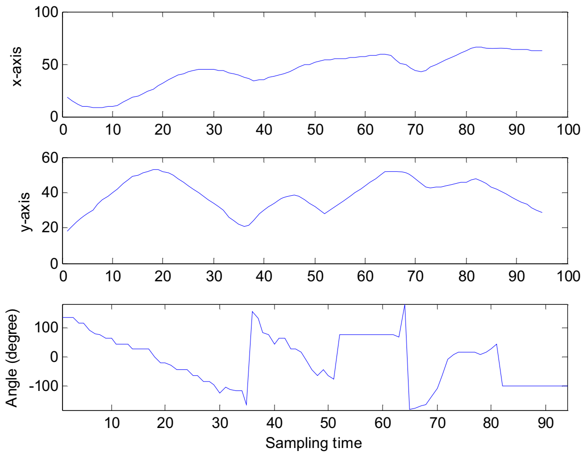

Fig. 2 Features of signature in (a) horizontal axis (b) vertical axis (c) angle representation

problem, False Rejection Rate (FRR) and False Acceptance Rate (FAR). The level of these two error rates depends on the decision threshold chosen whose value is such as to realize the Equal Error Rate (EER; FAR = FRR). All experiments are tested through existing Internet connection. Own developed programming based Java Servlet is employed.

In particular, the contributions of this paper are i) the concept of using angular transformation for online signature verification ii) the verification process using many decidion making from extracted components and iii) its performances through real-time Internet applications in comparing with other methods. The remainder of paper is organized as follows. In the following section, we describe the online signature processing including angular transformation and error-delay estimations. Section III provides the details of programming for e-Commerce services and then the verification procedure through such a program is described in Section IV. After showing the experimental results in Section V, we conclude in Section VI.

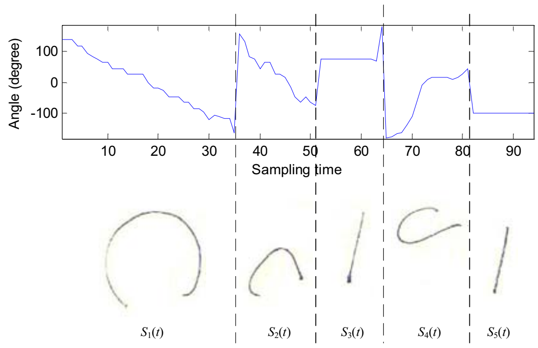

Fig. 3 Example of extracting components from angle representation

II. Online Signature Processing

A. Angular Transformation

In general, the handwriting signature are captured and represented in 2 dimensions, horizontal and vertical axes. For angular transformation, the domain considered instead of both axes is the angle domain which is calculated by slope from one captured point to another. The example of angular transformation is shown in Fig. 1. Fig. 2 presents the value of signature in term of horizontal, vertical and angular values in time. For proposed technique, only angular values of signature are transmitted from client to server. Hence, it saves some overheads due to reducing the size of signature feature.

As seen in Fig. 2(c), the plot of angular representation has many discontinuous points. These positions indicate two meanings, sharp tip and crossing pi. For sharp tip, it is the position when stroke of signature is started. The other discontinuous potion is a crossing pi because it is occurred when angular value is changing between opposite sign at 180 degree. Both meanings are helpful for angular transformation to extract signature into many components. The example of extraction is illustrated in Fig. 3 and expressed in (1).

$$S(t) = \sum_{i=1}^{M} S_i(t) \tag{1}$$

where M is the total components of signature, $S(t)$ is the angular representation of handwriting signature and $S_i(t)$ is the ith components of $S(t)$ which is defined by

$$S_i(t) = \begin{cases} S(t) & ts_i \le t \le te_i \\ 0 & elsewhere \end{cases} \tag{2}$$

where ts_i is the starting time of ith component and te_i is the ending time of ith comoponent.

B. Delay and Error Estimations

The angular transformation has been done in the client side and sent to server. After extracting all components by server,

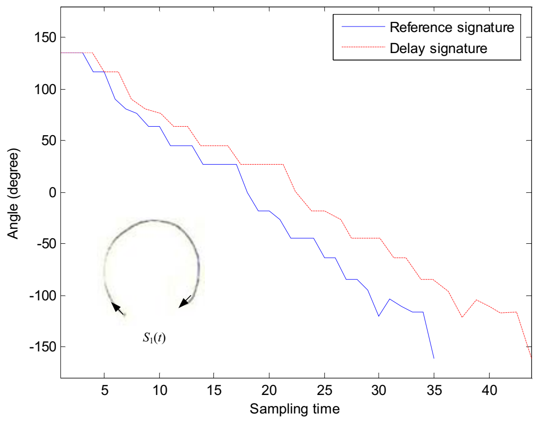

Fig. 4 Comparison between reference and delay signatures of first component shown in Fig. 3

the next process is to estimate delay shift and then calculate the errors. For online system, the time usage of writing signature becomes the most important information to be used for verifying process. This value is uniquely different from offline verification because the offline system cannot capture this delay time. In this paper, the linear approximation is applied to estimate the delay.

Fig. 4 shows the angular values of the first component presented in Fig. 3. The reference signature is the selected prototype used for comparing with testing signature. The method to choose reference signature will be described in the next section. As seen in Fig. 4, both signature have a similar trend but spreading by different times. Hence the delay shift d_i of ith component can be defined as

$$S_i^d(t) = S_i^r(d_i t) \tag{3}$$

where $S_i^r(t)$ is the ith component of reference signature and $S_i^d(t)$ is the ith component of delay signature.

To illustrate the relation between reference and delay signatures, the time intervals of both signatures are necessary to be investigated. Fig. 5 presents time intervals of first components given in Fig. 4. It is clearly seen that the slope of Fig. 5 is approximately defined by delay shift d_i. Using linear approximation shown in (4), then the delay shift can be easily estimated.

$$d_i = \min_{d_i}\left\{\sum_{t_i^r}\left|t_i^d - d_i t_i^r\right|^2\right\} \tag{4}$$

After estimating the delay shift, the estimated signature by compensating the delay shift can be expressed as

$$\tilde{S}_i^d(t) = S_i^d(t/d_i) \tag{5}$$

Fig. 6 shows the comparison between the first components of reference and estimated signatures derived by signatures presented in Fig. 4. It is noticed that there is some errors

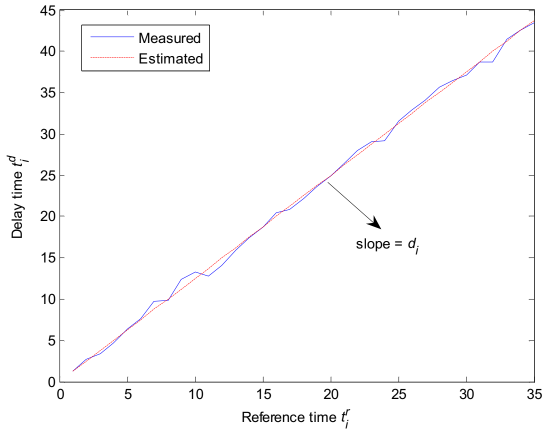

Fig. 5 Approximating the delay shift by slope of estimated line

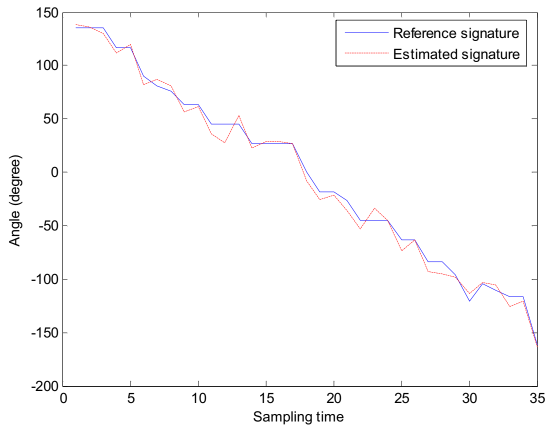

Fig. 6 Comparison between reference and estimated signatures

between them which summation of square errors can be expressed by

$$e_i = \sum_t \left|\tilde{S}_i^d(t) - S_i^r(t)\right|^2 \tag{6}$$

III. PROGRAMMING FOR E-COMMERCE SERVICES

This paper aims to implement the proposed technique for e-Commerce services. Therefore, the platform to support this idea are simulated by own developing program. In this paper, the Java Servlet is used to program both client and server interfaces. Fig. 7 demonstrates the connection between client and server for online verification. For client, the tablet pen mouse is attached to make a signature writing more comfortable. After digital handwriting signature is transformed into angular domains, the client program will transmit this data to server side through normal TCP/IP protocol in which any internet browser can be used.

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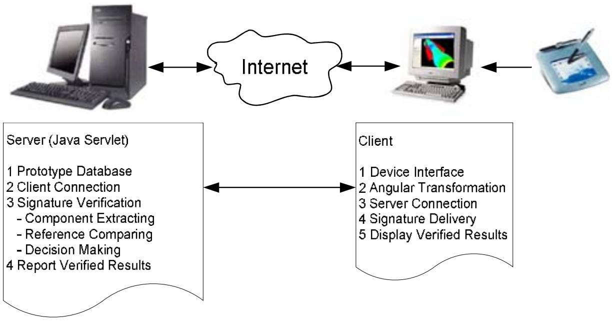


Fig.7 Connection between server and client

For server side, all training signatures are collected in the database for comparing with the data transmitted by client. Only matched signature will be authorized into the other section of web site otherwise the rejection will be transmitted back to client. Fig. 8 illustrated a program screen at client side opened by internet explorer.

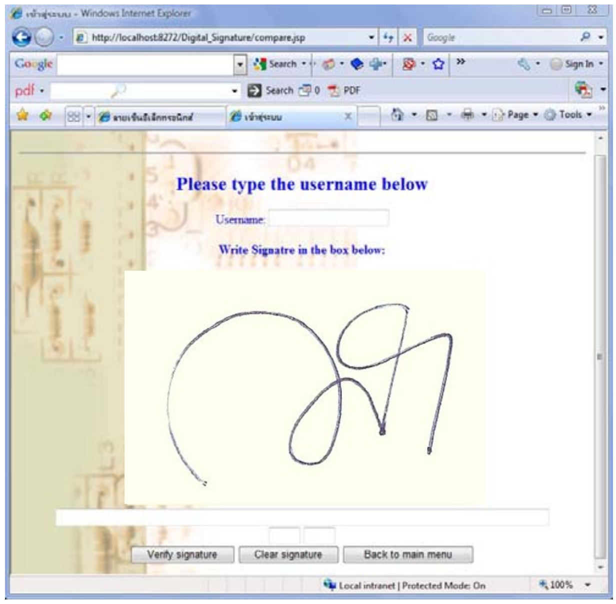


Fig. 8 Example of screen short at the client side to input the signature

IV. Verification Procedures

A. Signature Input Interface

Signatures are input by using a commercial electronic pencil and a tablet. The apparatus used in the experiments samples horizontal and vertical positions 150 times per second. The low-pass filtering and the size and direction normalization are applied on the input signature signals. The feature profile is extracted from the preprocessed input signal. All captured features are performed by Java programming.

B. Angular Transformation

An angular transformation is applied to the signature feature profile at client side. As described earlier, the delay shift estimation can be calculated by comparing with the reference signature. However, only server has these references, the process of estimating delay shift is carried out at server. Using only this angular feature, the component extraction is easily performed by considering the discontinuous point in time. By extracting process, the server can categorize signatures by number of components M. This can improve the speed of cross check between similar signature features. In addition, it can increase the quality of verification by M time examinations.

C. Selection of Reference Signature

One authorized user has been request to input multiple N signatures when registering. In this paper only one reference signature is chosen from those registered signatures. However, the criteria to choose reference signature depends on the delay shift and error estimations. The average value of delay shift and error estimations when use each registered signatures as a referenced signature among those N signatures can be expressed by

$$d_i(k) = \frac{1}{N-1}\sum_{l}^{N-1} \arg\left\{ \min_{d_i(k,l)} \left\{ \sum_{t_i^k} \left| t_i^l - d_i(k,l)\, t_i^k \right|^2 \right\} \right\} \qquad (7)$$

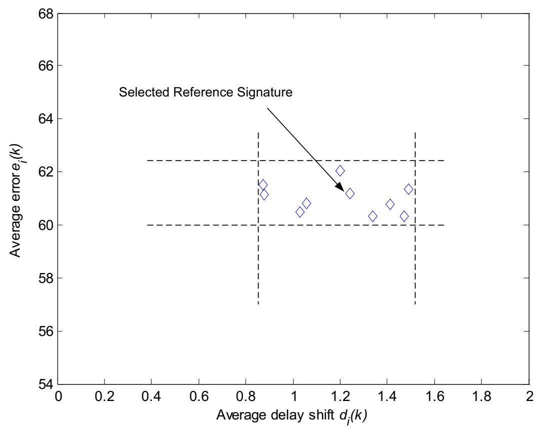


Fig. 9 Selecting reference signature

$$e_i(k) = \frac{1}{N-1}\sum_{l}^{N-1}\sum_{t} \left| \tilde{S}_i^l(t) - S_i^k(t) \right|^2 \qquad (8)$$

where $k, l = 1, \ldots, N$ and $k \neq l$

Fig. 9 presents the example of average delay shift and average errors from 10 registered signatures. The reference signature is selected from the one closest to the center.

D. Selection of Delay and Error Thresholds

For each authorized client, verification learning is done only on registered signatures. The server approximates, during the verification phase, the score of the signature. Signature verification for client I was performed using a decision

TABLE II
SIGNATURE VERIFICATION RESULTS FOR 10 CLIENTS

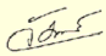
Client	Correct (%)	FRR (%)	FAR (%)
	95.13	2.51	2.36
	97.17	1.46	1.37
	91.24	4.51	4.25
	95.28	2.44	2.28
	97.59	1.22	1.19
	91.36	4.41	4.23
	95.16	2.48	2.36
	95.72	2.21	2.07
	97.45	1.34	1.21
	97.8	1.12	1.08

TABLE III
COMPARISON WITH OTHER METHODS

Methods	All tested Signatures		All Forgeries	
	FRR (%)	FAR (%)	FRR (%)	FAR (%)
Angular without extracting components	11.13	10.97	18.42	17.73
DP matching	9.46	9.29	15.09	14.76
Basic matching	15.63	14.88	22.43	21.32
Proposed	2.37	2.24	7.21	7.04

TABLE I
SIGNATURE VERIFICATION RESULTS FOR NUMBER OF TRAINING SIGNATURES

Number of Training Signatures	All tested Signatures		All Forgeries	
	FRR (%)	FAR (%)	FRR (%)	FAR (%)
4	4.56	4.42	12.26	11.98
6	3.31	3.19	9.25	8.97
8	2.54	2.36	7.84	7.53
10	2.37	2.24	7.21	7.04

V. EXPERIMENTS AND RESULTS

The dataset used in the experiment is composed of 300 signatures produced by 10 clients writing 20 registered/tested signatures and 100 forgery signatures forged by 10 volunteers. The server and client are on the same local area network. The proposed signature-verification algorithm was implemented with Java Servlet compiler. We compared the performance of the proposed algorithm with a DP matching-based functional approach [7] which was developed by one of the authors. The DP matching-based method selects multiple prototypes by using ISODATA clustering algorithm.

A. Number of Training Signatures

It is natural that the possibility of selecting an appropriate reference signature increases as the number of training samples increases. In addition, because the decision threshold is computed from FAR and FRR among the tested signatures, if the number of training samples is too small, selecting the decision boundary for deciding authentic or forged signatures will also be difficult.

Table I shows the verification results when increasing number of training signatures. The results from all registered signatures are better than forgeries. This is because the forgery signatures have more variety features than registered clients.

B. Verification Results

Table II presents the verification results of 10 clients for 10 training signatures. The proposed technique can offer average 95.39% correct verification. It is also noticed that the complex signatures provide low correct rate and high FRR/FAR.

C. Comparison with Other Methods

To illustrate the performance of our proposed method, we compared the results with other approaches which are the angular transformation without extracting components, DP matching [7] and basic matching methods. For proposed method, the decision making is done under the conclusion of all components extracted from signature. However, it is interesting to see whether only one feature without extraction produces the different results or not. For basic matching method, we use four combinations of signature's length, time, size and number of turning curve.

Table III presents the comparison results between proposed method and others. The proposed method can provide 7% and 7.7% better than DP matching based signature-verification method for all tested signatures and forgeries respectively. In addition, the signature verification with extracting components offers more reliable verification results than using a whole decision making. This is because the use of component extraction can screen dissimilarities of other signatures before making a decision. As seen in Table III, it is obvious that the basic matching approach is the worst verification but it needs, however, the least complexity for implementation.

VI. Conclusion

In this paper, we propose an online signature verification using angular transformation for e-Commerce services. To more effectively avoid the copy problem, the angular features of signatures in the form of delay shifts are examined. In addition, it is easy for angular feature to extract a whole signature into many components so the decision making has to be relied on individual judgment of each component. This procedure increases the verification correction rate. By own developing server-client program, the verification results are able to collect through Internet connection. Experimental results show that the proposed method could compare more accurate than other approaches.

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Peerapong Uthansakul (M'07) received B.Eng and M.Eng degrees from Chulalongkorn University, Thailand in 1996 and 1998, respectively. In 1998-2000, he worked as Telecommunication Engineer with Telephone Organization of Thailand (TOT) and then he has joined Suranaree University of Technology since 2000. During 2003-2007, he studied PhD at University of Queensland, Australia, in the area of wireless communications especially MIMO technology.

He currently works as Assistant Professor in school of Telecommunication Engineering, Faculty of Engineering, Suranaree Unviersity of Technology, Thailand. He wrote 1 book entitled Adaptive MIMO Systems: Explorations for Indoor Wireless Communications (also available on amazon.com) and he has published more than 60 referee journal and conference papers. His current research interests include MIMO, OFDM, WiMAX and Wireless Mesh Network.

Dr. Uthansakul received 2005 Best Student Presentation Prize winner at the 9th Australian Symposium on Antennas, Sydney, 16-17 February 2005, Australia and 2004 Young Scientist Travel Grant winner at the 2004 International Symposium on Antenna and Propagation, 17-21 August 2004, Japan.

Monthippa Uthansakul (M'07) received B.Eng degree from Suranaree University of Technology, Thailand, in 1997 and M.Eng degrees from Chulalongkorn University, Thailand in 1999. She has joined Suranaree University of Technology since 1999. During 2003-2007, she studied PhD at University of Queensland, Australia, in the area of smart antenna especially wideband beamforming.

She currently works as Assistant Professor in school of Telecommunication Engineering, Faculty of Engineering, Suranaree Unviersity of Technology, Thailand. She wrote 1 book chapter entitled Wideband smart antenna avoiding tapped-delay lines and filters in Handbook on Advancements in Smart Antenna Technologies for Wireless Networks, Idea Group Publishing, USA, 2008 and she has published more than 50 referee journal and conference papers. Her current research interests include antenna array processing, compact switched beam antenna and body communications.

Dr. Uthansakul received Young Scientist Contest 2nd Prize at 16th International Conference on Microwaves, Radar and Wireless Communications, Krakow, Poland, 22-24 May 2006.