Online Person Authentication using dynamic signature on a Novel tactile and pressure sensitive pad

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Abstract— The demand for biometric application in security, in human computer interaction, mobile phones and PDA's concerning tactile screen & pads and related areas is rapidly increasing. This paper presents very simple and low cost, novel tactile and pressure sensitive writing pad for input of handwritten characters or signatures. The dynamics of handwriting movement are recorded with a novel tactile input device in combination of commonly used pen in terms of capturing the tactile effects and pressures of pen tip on writing pad. The writing pad or tactile screen is constructed using piezoelectric foil underneath the plastic writing pad. The tactile screen can also be used as an input device for handwriting recognition. Features of the device and evaluation of the signals produced are discussed. Encouraging experimental results for person authentication are obtained using handwritten signature based on Dynamic Time Warping (DTW) technique with such a low cost and simple tactile biometric system. Further excellent accuracy in person authentication was achieved which is mainly due to DTW technique and a novel simple input device.

Keywords— biometric person authentication, dynamic time warping DTW, pressure sensitive tablet, signature verification.

I. INTRODUCTION

With the increasing use of tactile screens or pads concerning human interactions in computers, mobile phones and PDA's etc, the demand for authentication has essentially increased. Therefore reliable person authentication is becoming more important because the need to avoid unauthorized access for interactions in almost every part of life. Although non-biometric authentication methods based on ownership (keys or cards) or knowledge (e.g. passwords) are still widely used but it is not possible to fully avoid non-authentic possessions. Biometric authentication methods offer high security standards [1],[2],[3]. Biometric authentication systems can be divided into physiological (e.g. hand geometry, finger prints) or behavioral characteristics of a person (e.g. signature, handwriting, speech or gait). The authentication by handwriting or signatures is important and has advantage over other biometrics because of more widely acceptance in public and the convenience of the pen and paper. Biometric signature authentication can be divided into offline authentication based on static images of handwritten signatures and online authentication based on dynamics of the signatures of a person. Later is suitable choice for reliable authentication in comparison to static images because handwriting dynamics include pressures, velocities and accelerations measurements which also reflect human fine motor skills [1],[2],[7],[9],[10],[11]. Further the dynamics of the writers are apparently much harder to be imitated by others than that of static image of handwriting [7]. Many online signature input systems have been proposed. Generally the dynamics of handwriting during handwritten signatures are recording with the help of special pen with several sensors or/and graphic tablet or pressure sensitive pad [1-8].

A novel tactile and pressure sensitive writing pad or screen has been developed which is used in combination of a commonly used ballpoint pen and paper for the online input of handwritten characters or signatures. The sensor for recording dynamics of handwriting is mounted underneath the writing area of writing pad (see section II). For online signature verification, in parameter based approach the features describing the characteristics of signature are extracted and used for person identity verification. On the other hand in functional based approaches the complete signals or time series generated during signing process are used. Later approach essentially retains more signing information and generates more accurate results [1],[7],[17] is used in the work presented in this paper.

In order to minimize the problem of high variability [1] of repeated copying of signatures written by the same writer Dynamic Time Warping (DTW) based classifiers [4], [12], [13] is used.

In this paper biometric person authentication using handwritten signatures based on DTW using a tactile and pressure sensitive pad and commonly used pen is presented. The paper is organized as follows. In Section II the novel writing pad used in the experiments for data acquisition is described. Section III briefly outlines the DTW based classifier. Then in Section IV results of the experimental work of evaluation are presented and discussed. Section V finally summarizes the major findings and highlights the prospects of application.

II. TACTILE AND PRESSURE SENSITIVE WRITING PAD FOR DATA ACQUISITION

A novel tactile and pressure sensitive writing pad or screen has been developed which is used in combination of a commonly used ballpoint pen for the online input of handwritten characters or signatures. The sensor (piezoelectric polymer foil) for recording dynamics of handwriting is mounted underneath the writing pad behaves as touch screen and pressure sensing element. The pressures exerted by the fingers on pen tip during handwriting are dynamic ones which is the attraction in the selection of dynamic pressure sensing piezoelectric foil (PEF) as pressure sensor in the acquisition

device. The ability to measure miscellaneous pressures, lift off & retouch of pen tip and writing surface with respect to time

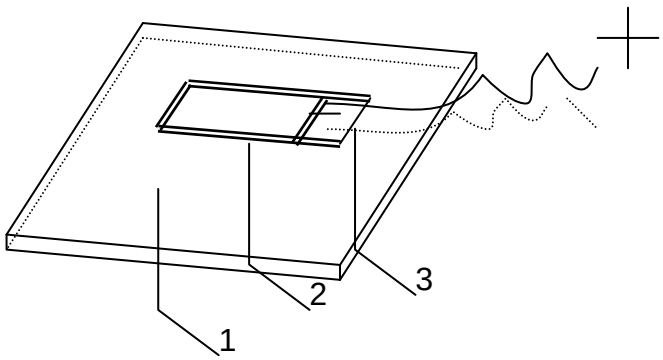

Fig.1 schematic diagram of tactile and pressure sensitive writing pad.

axis are key biometric features and are the main potential of the input device. The schematic diagram of writing pad used for person authentication using signatures is shown in the Fig 1.

The pen and pad based system provides sensor signals low pass filtered, amplified and digitized by a 12 bit A/D converter at a sampling frequency of 500Hz. The digital data are transferred to a computer by a wired (HID-USB) transmission technology.

Fig.1 shows the schematic diagram of writing pad. It consists of 3 main parts. Part 1 is plastic writing pad and writing surface area for input of handwriting characters or signatures on a common paper placed on the writing pad. Part 2 is piezoelectric polymer foil (PEF) pressure and tactile sensor embedded underneath the writing pad which makes the writing pad as touch screen and pressure sensing element. And part 3 shows the positive and negative terminals of PEF go to amplifier.

Typical time series recorded with the input device for handwritten signatures are shown in Fig. 2. The

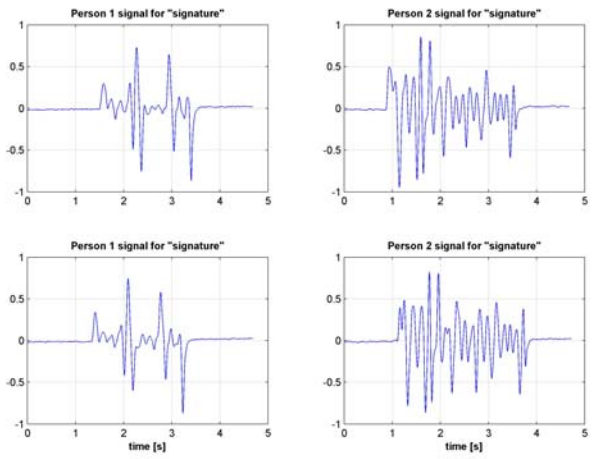

Fig. 2 Typical output of time series for same (columns) and different writers (rows) recorded with input device writing two signatures.

characteristics features of the time series are essentially determined by the type of written item and by the fine motor movements of the writing person. Examples for great similarities between signals obtained from signatures of same writer and distinctiveness of signals for signatures obtained from different writers are shown in the Fig 2. The signals obtained for signatures essentially show enough person specific biometrics information are contained in one time series obtained from simple, low cost, tactile and pressure sensing writing pad with the help of commonly used ballpoint pen.

DTW algorithm is applied for time series analysis for online person authentication using handwritten signatures.

III. Dynamic Time Warping Classifier

Dynamic Time Warping DTW is known to be useful for classifying human individuals based on a similarity match of time series obtained from signatures. One of the advantages of DTW is that it is able to match two time series $S = (s_1, s_2, \ldots\ldots s_n)$ and $R = (r_1, r_2, \ldots\ldots r_m)$ of unequal length $n \neq m$. Further DTW based classification yields a high performance even for time series of small string length. DTW measures the similarity of two time series (S, R) in terms of the distance between S and R after they have been warped together. The distance value is found by minimizing a cumulative cost which is defined by the Euclidean distances between all matches (s_i, r_j).Given an unknown sample S, the DTW based classifier calculates the distances to all references R among a population (persons, characters, etc.), sorts them by distance, and returns a list of nearest references. The minimum-distance of the top best match decides for classification [4]. The description of DTW is necessarily brief. For more details see [14],[16], [19].

Due to the quadratic time and space complexity O(nm) standard DTW has computing time and memory space problems. To speed up computations some approaches are described in [15],[16],[17],[18][23]. The computing time can also be reduced by down-sampling of data [22]. The aim of this work is to evaluate the proposed input device for online input of signatures and person authentication based on DTW.

Fig. 3 shows two time series obtained from signatures from same writer before and after DTW. The non-linear time shifts in the two time series are minimized with the help of DTW

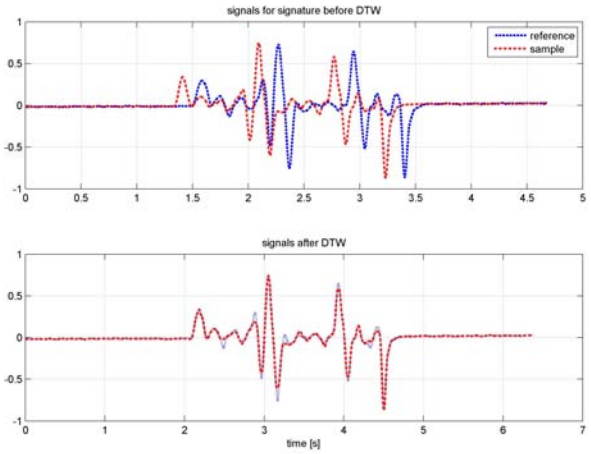

Fig. 3 time series for same writer recorded with input device writing two signatures before and after DTW.

technique.

For similar time series, DTW distance is essentially small contrary to large DTW distance values in case of dissimilar time series.

A. Performance and Accuracy

The performance of hardware and software is evaluated in terms of calculating the accuracy of classification of human individual based on signatures and the receiver operating characteristic ROC curve which is commonly used for the evaluation of biometric person recognition system[4],[22].
Receiver Operating Characteristic ROC of a biometric classification system is a graphical depiction of the relationship between the False Rejection Rate FRR and False Acceptance Rate FAR as a function of the decision threshold's value. The area under the ROC curve AUC with ≤ 1 is a well suited measure to evaluate the performance of recognition. The better the performance, the greater the area under the ROC curve. For more details of ROC in biometric person recognition see [20].

IV. Experiments and Results

The main objective of the experiments was evaluation of proposed signature input device for online person authentication using handwritten signatures with the help of DTW technique.

A. Data Base

The database used in the experiments is collected from 10 different persons each writing their own signatures 9 times. The corresponding database covers 90 samples for signatures.
Ten persons signed on the writing pad in sequence under optimal similar conditions because the collection of samples from a candidate was accomplished during single session, keeping the variability low. For the evaluation task the database is subdivided in query (test) and reference (prototype) samples. In order to evaluate the performance more critically, out of 90 samples for signatures one out all in technique is used.

B. Preprocessing of time series

The DTW match was performed after an adequate preprocessing of the original signal data. The time series are smoothed, segmented, normalized and down-sampled without discarding valuable information. Smoothing of data is performed to eliminate potential sensor noise. All signatures are recorded separately so that no additional segmentation of signals is required in our study work. All signals are normalized to rescale to [-1,1]. Re-sampling of data to lower sampling rate is done to reduce the computational time. Data preprocessing and DTW is implemented in MATLAB [21]. For details of data preprocessing the reader is referred to [4].

C. Online Person authentication

For online biometric person authentication using signatures one query of a person out of all samples (all persons) is repeatedly selected and is compared against the remaining set of all samples. In order to evaluate the performance more critically, out of all samples for signatures, one out all in technique is used. If DTW is applied to signals down-sampled to 6^{th} part of original data then the excellent accuracy of 99.8% is achieved. The receiver operating characteristic ROC is determined for the evaluation of person authentication as shown in the Fig. 4 the area under the curve ($AUC \geq 0.996$) indicates an excellent grade

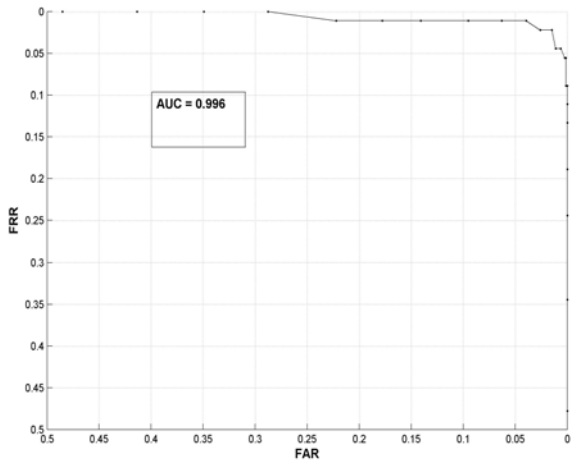

Fig. 4 ROC curve for person authentication using signatures

of performance. The values are averaged over all writers and down-sampling of data to 6^{th} part of original data are used. This mainly reveals the high quality of the signals obtained from input device used for DTW. The computational time can significantly be reduced by making use of dawn-sampling of data or involving the state of the art fast DTW techniques.

V. Conclusion

It is found that the simple, low cost one channel, tactile and pressure sensitive writing pad can be employed as input device for input of signatures for person authentication. The proposed input device can also be used to input handwritten characters for handwriting recognition.
It is observed that the proposed input device has the ability to measure miscellaneous pressures, lift off & retouch of pen tip and writing surface with respect to time axis are the key biometric features and are the main potential of the input device.
Because of simplicity, small size and low cost sensor, the proposed technique can be used in emerging touch screens or writing pads in human computer interactions and authentication applications. Encouraging person authentication results with handwritten signatures on the writing pad are achieved (accuracy and ROC AUC > 99%). The further work is to extend research work for forgery tests on big population of writers and to do handwriting recognition tasks.

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REFERENCES

[1] C. Gruber, C. Hook, J. Kempf, G. Scharfenberg, B. Sick, " A Flexible Architecture for Online Signature Verification Based on a Novel Biometric Pen" In Proceedings of the 2006 IEEE Mountain Workshop on Adaptive and Learning Systems (SMCals/06)"; pp. 110-115; Logan, 2006

[2] T. Gruber, C. Gruber, B. Sick, " Online Signature Verification With new Time Series Kernels for Support Vector Machines" D. Zhang, A. K. Jain (Eds.) Advances in Biometrics: International Conference ICB 2006; Lecture Notes in Computer Science 3832, Springer Verlag, Berlin, Heidelberg, New York; pp. 500-508; Hong Kong, 2006

[3] Hook C., Kempf J., Scharfenberg, G. "New Pen Device for Biometrical 3D Pressure Analysis of Handwritten Characters, Words and Signatures." Proceedings ACM Multimedia Berkeley, USA (2003) 38-44

[4] Muzaffar Bashir, Jürgen Kempf, "Reduced Dynamic Time Warping for Handwriting Recognition Based on Multi-dimensional Time Series of a Novel Pen Device", In International Journal of Intelligent Systems and Technologies, vol.3.4, Paris WASET Fall 2008.

[5] Hook C., Kempf J., Scharfenberg G, "A Novel Digitizing Pen for the Analysis of Pen Pressure and Inclination in handwriting Biometrics", Biometric Authentication Workshop, Prague 2004, Lecture Notes in Computer Science. Springer 2004.

[6] Šoule M., Kempf J. "Handwritten Text Analysis through Sound. A New Device for Handwriting Analysis", In Proceedings IWSSIP, Prague, (2003) 254-257

[7] Pin F, Zhong C.W, Min M., Yun J.G, "An improved F-Tablet for handwriting signal capture", In Int. Conf. on Information Acquisition IEEE 2004.

[8] Šoule, M, "Person Authentification Using Acoustic Handwritten Text", Ph.D. thesis, Pilsen (2007), Czech Republic.

[9] M. Dose, C. Gruber, A. Grunz, C. Hook, J. Kempf, G. Scharfenberg, B. Sick, "Towards an Automated Analysis of Neuroleptics' Impact on Human Hand Motor Skills", In Proceedings of the 2007 IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB 2007)"; pp. 494-501, Honolulu, 2007

[10] A. Ünlü, R. Brause, K. Krakow," Handwriting Analysis for Diagnosis and Prognosis of Parkinson's Disease", Proc.Int. Symp. Biological and Medical Data analysis, LNCS Vol. 4345,Springer Heidelberg 2006,pp.441-450

[11] TakitaT., Hangai S., Kempf J, Hook C., Scharfenberg G., "An Identification of Japanese Numerical Characters on a Biometrical Smart Pen System", In Automatic Identification Advanced Technologies, 2007 IEEE Workshop, June 2007.

[12] R. Niels, L. Vuurpijl, "Dynamic Time Warping Applied to Tamil Character Recognition". Proceedings of the 8th International Conference on Document Analysis and Recognition, 2005.

[13] Marcos Faundez Zanuy, "On-line signature recognition based on VQ-DTW", ELSEVIER, June, 2006.

[14] Eamonn J. Keogh, Michael J. Pazzani, "Derivative Dynamic Time Warping" In Proc. Of the 1st SIAM Int.Conf. on Data Mining (SDM-2001).

[15] V. Vuori, J. Laaksonen, E. Oja, J. Kangas, "Speeding up On-line Recognition of Handwritten Characters by Pruning the Prototype Set" In Proc.Of (ICDAR'01), pp.501-505.

[16] Eamonn J. Keogh, Michael J. Pazzani. "Scaling up dynamic Time Warping for Data mining Applications". In Proc. 6th Int. Conf. on Knowlegde Discovery and Data Mining. KDD(2000).

[17] Hao F, Chan C. Wah. "Online signature verification using a new extreme points warping technique". In pattern recognition letter vol.24, Elsevier Science NY (2003).

[18] Salvador S., Chan P.: "FastDTW: Toward Accurate Dynamic Time Warping in Linear Time and Space", Intelligent Data Analysis, 2007.

[19] H. Sakoe, S. Chiba, "Dynamic programming algorithm optimization for spoken word recognition". IEEE Transaction on Acoustics, Speech and Signal Processing, Vol 26, NO1, pp. 43-49. February 1978.

[20] http://www.bromba.com/faq/biofaqe.htm#ROC

[21] www.mathworks.com

[22] Muzaffar Bashir, Jürgen Kempf. "Person Authentication with RDTW using Handwritten PIN and signature with a Novel Biometric Smart Pen Device". In SSCI Computational Intelligence in Biometrics, IEEE, Nashville (2009).

[23] Eamonn Keogh, Chotirat Ann Ratanamahatana. "Exact indexing of dynamic time warping". In Knowledge and Information Systems 358-386, Springer London, (2004).