UNITECH 2020 GABROVO

INTERNATIONAL SCIENTIFIC CONFERENCE
20-21 November 2020, GABROVO

PERFORMANCE OF THE MTSENG ALGORITHM FOR BIOMETRIC ON-LINE VERIFICATION HANDWRITTEN SIGNATURE

Milivojević Zoran[1], Milivojević Marina[2]
[1] *Academy of Applied Technical and Preschool Studies, Section Niš, Niš, Serbia.*
zoran.milivojevic@vtsnis.edu.rs
[2] *Mikkelsen Electronics, Niš, Serbia. marina.milivojevic82@gmail.com*

Abstract

The first part of the paper describes the Tseng algorithm for on-line handwritten signatures verification. After that, the MTseng algorithm , which was created by modifying the Tseng algorithm, in order to increase the accuracy of verification, was presented. Then, an algorithm for determining the decision threshold is presented. The algorithm is based on False Positive and False Negative error analysis. The second part of the paper describes an experiment in which the performance of a MTseng algorithm was determined using True Positive, True Negative, False Positive and False Negative errors. The mentioned errors are shown graphically and tabularly. Finally, the performed comparative analysis of the results shows a higher accuracy of the MTseng algorithm.

Keywords: on-line signature verification, biometric, dynamic time warping (DTW).

1. INTRODUCTION

When users access to computer systems, user authentication is usually performed using a username and password or a key phrase [1]. In order to increase the security of the system, identification systems based on biometrics are additionally used [2]. Within the biometric control, the following are analyzed: a) Physiological biometrics which based on some physical parts of the human body (fingerprints, faces, retinas, hand scan recognition, etc.), and b) Behavioral biometrics which based on measuring some characteristics and behavior of a person (signature, voice, etc.) [3]. Testing of biometric characteristics does not require additional resources (keys, magnetic cards, ...) [4]. In everyday life, the personal verification by handwritten signature has long been accepted [5]. Recognition of biometric characteristics refers to: a) identification and b) verification. Identification determines which user provides a biometric parameter among a set of known users. Verification determines whether a particular biometric parameter was given by a particular known user or is a forgery. Automatic signature verification plays a very important role in the set of biometric techniques for personal verification [6]. The paper [7] presents a detailed review of the literature published up to 1989. A review of the literature for the period from 1989 to 1993 is presented in [8].

Handwritten signature verification systems, depending on the method of data collection, are: a) *on-line* (dynamic) [9] and b) *off-line* (static), [10]. In on-line systems, during the duration of the signature, data on: a) position and b) pressure of the pen on the Touch display are generated. Based on the current position of the pen on touch display, velocity, acceleration, pressure and force, are calculated [11]. In the case of off-line systems, the analysis is performed after the completion of the signature. The signature is presented as an image obtained by scanners, cameras, etc. Verification is performed by algorithms for comparing the signature image with reference images from the database [12]. Off-line systems, unlike on-line systems, do not analyze the time characteristics of signatures. For a forger, it is very complex to write a signature by shape, velocity and acceleration simultaneously, so that the on-line method is more reliable than off-line. Two types of characteristics can be distinguished from the signature: a) local and b) global. Local characteristics refer to each point (x, y) of the signature (current positions, velocity, acceleration, pressure, force, etc.). Global characteristics refer to the whole signature (total time, average pressure, average speed, ...) [13].

The paper [14] describes an algorithm (Tseng algorithm) for reducing the error of the handwritten signature verification system. The Tseng algorithm is based on the application of zero (H_0) and first (H_1) order differentiators. Signature analysis is performed by determining Dynamic Time Warping (DTW distance - D_{DTW}) and comparing it with the user's reference signatures in the database. A decision is made according to the defined threshold Sg. In [14], the algorithm for determining the decision threshold S_{g} was not defined.

In this paper, the authors modified the Tseng algorithm to increase the accuracy of signature verification. The modification of the algorithm was performed by applying the duration of the entire signature T, as a global characteristic. In addition, the authors proposed an algorithm for determining the decision threshold Sg. The decision threshold was determined based on statistical error parameters: a) FAR (False Acceptance Rate) and b) FRR (False Rejection Rate). After that, the authors determined the verification accuracy of Tseng and the modified MTseng algorithm, by realizing the experiment and conducting a comparative analysis of the experimental results. As part of the experiment, a signature database was created. The test group was composed of students from the Academy of Applied Technical and Preschool Studies, Section Nis, Serbia, from the Department of Information and Communication Technologies. One part of the participants from the test group signed in their own handwriting. The task of the other part of the participants from the test group was to falsify the original signature. Using Tseng and MTseng algorithms, signatories were verified. The decision on authenticity (genuine / forgery) is made on the basis of the decision threshold (comparison of D_{DTW} distance with the S_{g} threshold). Verification accuracy was estimated based on PPV (Positive Predictive Value). The results of the experiment (distance D_{DWT}, FAR and FRR errors) are presented graphically and tabularly. Estimates of the accuracy of the Tseng and MTseng algorithms were performed: a) without signature preprocessing and b) with signature preprocessing. Preprocessing was performed: a) by normalizing the signatures in the y-axis direction and b) by overlapping the tested signatures along the y-axis in accordance with the mean values.

The organization of the paper is follows. Section II presents the Tseng and MTseng algorithms. Section III describes the experiment and a comparative analysis of the results. Section IV is the Conclusion.

2. HANDWRITTEN VERIFICATION ALGORITHMS

2.1 Teng algorithm

In [14], the Tseng signature verification algorithm is described. The Tseng algorithm is based on calculating the D_{DTW} distance between the reference (s_{R}) and the tested (s_{T}) signature. The Tseng algorithm consists of the following steps:

Input: signatures s_{R}: ($\mathbf{x}_{\mathrm{R}}$,$\mathbf{y}_{\mathrm{R}}$) i s_{T}: ($\mathbf{x}_{\mathrm{T}}$,$\mathbf{y}_{\mathrm{T}}$), decision threshold S_{g}.
Output: decision genuine / orgery

Step 1: position of the pen at the time n:

$$s_R(n) = x_R(n) + \mathrm{j} \cdot y_R(n), \tag{1}$$

$$s_T(n) = x_T(n) + \mathrm{j} \cdot y_T(n), \tag{2}$$

where is $\mathrm{j}=\sqrt{-1}$ the imaginary unit.

Step 2: Determine the pen position using a zero-order differentiator ($H_0(z)$):

$$s_R^{(0)}(n) = x_R^{(0)}(n) + \mathrm{j} \cdot y_R^{(0)}(n), \tag{3}$$

$$s_T^{(0)}(n) = x_T^{(0)}(n) + \mathrm{j} \cdot y_T^{(0)}(n), \tag{4}$$

Step 3: Determining of the DTW distance:

$$D_0 = DTW\left(s_R^{(0)}, s_T^{(0)}\right), \tag{5}$$

Step 4: Determination of the pen velocity using first-order differentiator (H_1 (z)):

$$s_R^{(1)}(n) = x_R^{(1)}(n) + \mathrm{j} \cdot y_R^{(1)}(n), \quad (6)$$

$$s_T^{(1)}(n) = x_T^{(1)}(n) + \mathrm{j} \cdot y_T^{(1)}(n), \quad (7)$$

Step 5: Determine of the DTW distance for the pen velocity:

$$D_1 = DTW\left(s_R^{(1)}, s_T^{(1)}\right), \quad (8)$$

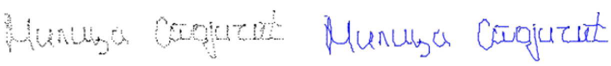
Step 6: Determining the equivalent DTW distance:

$$D_{DTW} = \frac{D_0 + D_1}{2}, \quad (9)$$

Step 7: Signature verification:

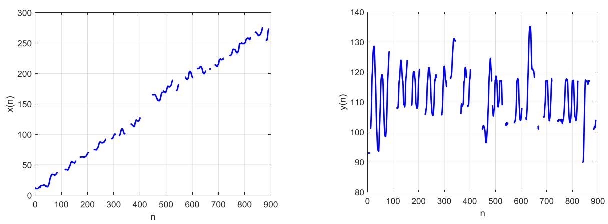
$$\text{decision} = \begin{cases} D_{DTW} \le S_g, \text{ genuine} \\ \text{otherwise forgery} \end{cases}, \quad (10)$$

Example of the MTseng algorithm application. The input signature for the Tseng algorithm is shown on Fig. 1: a) the pen positions in time and b) interpolation between points by linear interpolation. The discrete positions of the pen along the *x*-axis and *y*-axis, in the notation *x*(*n*) and *y*(*n*), respectively, determine the spatial position of the pen at time *n* (*Step 1*): a) Fig. 2.a (*x*(*n*)) and b) Fig. 2.b (*y*(*n*)). Figure 3 shows the current pen velocity *v* (m/s) along: a) the *x*-axis v_x (Fig. 3.a), b) *y*-axis v_y (Fig. 3.c) and c) tangential velocity v_t (Fig. 3.c).



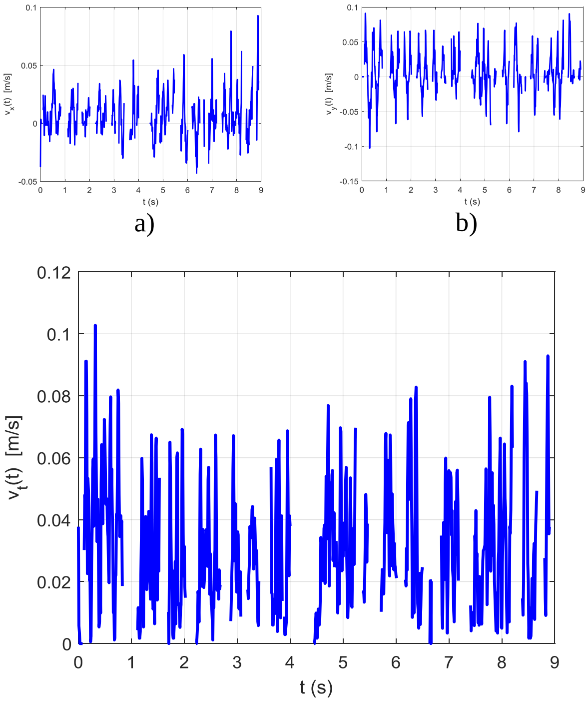
a) b)

Fig. 1. *a) the positions of the pen in time and b) the lines between the points determined by linear interpolation.*



a) b)

Fig. 2. *Positions of the pen along the a) x-axis and b) y-axis.*



a) b) c)

Fig. 3. *The pen velocity: a) v_x (t), b) v_y (t) and c) v_t (t).*

2.2 MTseng algorithm

In order to increase the accuracy of the signature verification, the authors modified the Tseng algorithm (MTseng algorithm). The modification was performed by introducing a correction factor *T*, which depends on the duration of the signature. Namely, the trained user realizes his signature in a shorter time in relation to the forger. The modification refers to *Step 6* of the Tseng algorithm (Section 2.1) which becomes:

Step 6: Determining the equivalent DTW distance:

$$D_{DTW} = \frac{D_0 + D_1}{2} T, \quad (11)$$

where *T* is the duration of the signature.

2.3 Algorithm for the decision threshold estimation

In the paper [14] did not analyze the decision threshold of Sg. The authors of this paper used an algorithm based on the control of the percentage of erroneous decisions: a) the correct signature was rejected as a forgery (False Rejection rate - FRR):

$$FRR = FNR = \frac{FN}{P} = \frac{FN}{FN + TP}, \quad (12)$$

and b) the forgery has been declared an authentic signature (False Accounted Rate - FAR).

$$FAR = FPR = \frac{FP}{N} = \frac{FP}{FP+TN}\,. \qquad (13)$$

The decision threshold is the point where the curves intersect and represents the Crossover Error Rate (CER), also known as the Equal Error Rate (EER). The algorithm for estimating the decision threshold S_g consists of the following steps:

Input: signatures s_R: $(\mathbf{x}_R, \mathbf{y}_R)$ i s_T: $(\mathbf{x}_T, \mathbf{y}_T)$.
Output: decision threshold S_g

Step 1: The distance D_{DTW} between the signatures s_R and s_T is calculated.
Step 2: for the decision threshold in the range *min*(DTV)-*max*(DTW), TP and TN errors are calculated.
Step 3: The optimal decision threshold is determined from the FRR and FAR equality:

$$FRR = FAR \Rightarrow S_g\,, \qquad (14)$$

The accuracy verification of the MTseng algorithm was determined experimentally.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Experiment

In order to examine the accuracy of signature verification by Tseng and MTseng algorithms, an experiment was performed. Within the experiment, the following was performed: a) creation of the Signature Test Database, b) determination of the decision threshold, c) classification of signatures and d) statistical analysis. The signatures of one participant in the experiment were considered original signatures (10 signatures genuine). The other five participants in the experiment were tasked with falsifying the original signatures. Each ‘forger’ forged the original signature 10 times (5x10 = 50 forgery signatures). The first five original signatures and the first five forged signatures were used to determine the decision threshold. Using the DTW algorithm, DTW distances (D_{DTW}) were calculated (125). Thereafter, FNR and FAR errors in the range *min*(D_{DTW}) to *max*(D_{DTW}) were determined. The decision threshold is determined from the equality of FNR and FAR errors. Decision thresholds are calculated for cases: a) when there isn't and b) when there is a signature correction by the correction factor T. After that, based on the remaining five signatures of the genuine and five signatures of forgeries each, D_{DTW} distances were calculated and, after comparison with the previously defined decision thresholds S_g, a decision was made on whether the signature was genuine or forged. Verification accuracy was calculated based on the parameters: a) True Positive, TP (the original signature was recognized as the original), b) True Negative, TN (the forgery was rejected), c) False Positive, FP (forgery accepted as original), e) False Negative, FN (original rejected as forgery), e) FRR False Rejection Rate, FRR and f) False Accounted Rate, FAR. Verification accuracy was determined using PPV (Positive Predictive Value):

$$PPV = \frac{TP}{TP+FP}\,, \qquad (15)$$

The verification accuracy of the Tseng and MTseng algorithms was tested for signatures: a) without normalization (Experiment E1), b) normalized along the *y*-axis (Experiment E2) and c) equalized by the mean value along the y-axis (Experiment E3).

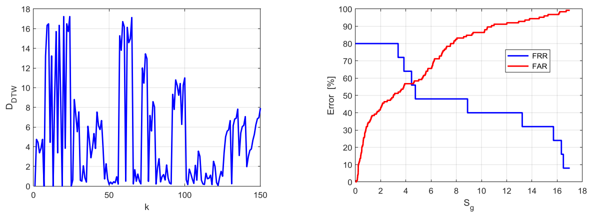
3.2 Test Base

A test database of signatures was formed by archiving the signatures of students of the Academy of Technical and Educational Studies from the Department of Information and Communication Technologies, Nis, Serbia. Archiving was done using Touch display dimensions M = 240 and N = 320 points (48.768 mm x 65.024 mm). The pen positions on the Touch display were measured at T_s = 0.01 s.

3.3 Results

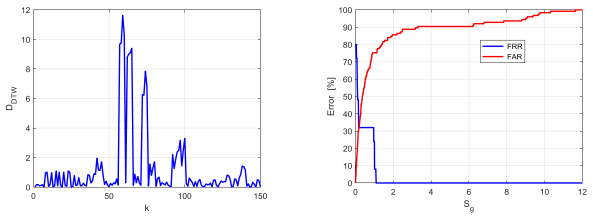
The DTW distance (D_{DTW}) for the zero-differentiation (Experiment E1) is shown in Fig. 4.a. The errors from which the decision threshold Sg is determined are shown in Fig. 4.b. The D_{DTW} distance for signatures corrected by factor T, shown in Fig. 5.a. The errors from which the decision threshold Sg is determined are shown in Fig. 5.b. The D_{DTW}

distance for normalized signatures (Experiment E2) is shown in Fig. 6.a while the errors are shown in Fig. 6.b. Fig. 7.a shows the distances, while the errors after correction by factor T are shown in Fig. 7.b. Fig. 8.a shows the distance and Fig. 8.b the error with signatures with equal mean (Experiment E3). Fig. 9.a shows the distances, while the errors after correction by factor T are shown in Fig. 9.b. Numerical values of decision thresholds, statistical parameters and verification accuracy are shown in Tables 1 (Tseng algorithm) and Table 2 (MTseng algorithm).



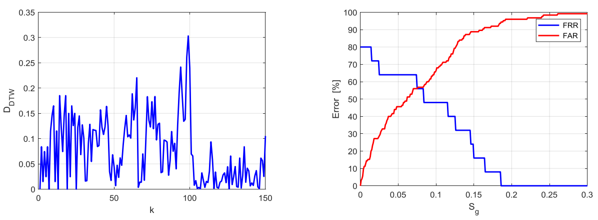
a) b)

Fig. 4. *Signatures without normalization and without time correction: a) D_{DTW} distance and b) FRR and FAR errors (Tseng algorithm).*



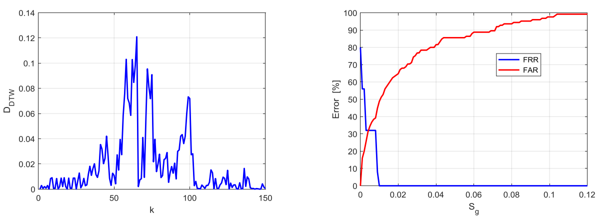
a) b)

Fig. 5. *Signatures without normalization with time correction: a) D_{DTW} distance and b) FRR and FAR errors (Tseng algorithm).*



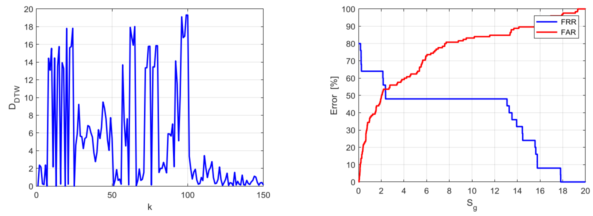
a) b)

Fig. 6. *Signatures with normalization and without time correction: a) D_{DTW} distance and b) FRR and FAR errors (Tseng algorithm).*



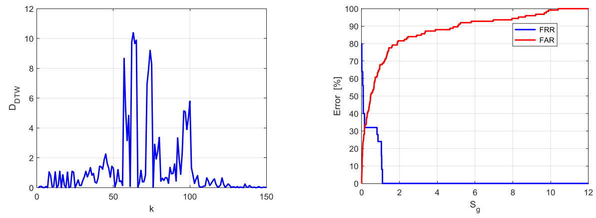
a) b)

Fig. 7. *Signatures with normalization and without time correction: a) D_{DTW} distance and b) FRR and FAR errors (Tseng algorithm).*



a) b)

Fig. 8. *Signatures with equalization by the mean value along the y-axis and without time correction: a) D_{DTW} distance and b) FRR and FAR error errors (Tseng algorithm).*



a) b)

Fig. 9. *Signatures with equalization by the mean value along the y-axis and with time correction: a) D_{DTW} distance and b) FRR and FAR error errors (Tseng algorithm).*

Table 1. Decision thresholds, statistical parameters and verification accuracy of Tseng algorithm.

Experiment	E1	E2	E3
Sg	4.4520	0.075	2.3740
EER (%)	56	56	52
TP	11	11	12
FP	71	70	67
FN	14	14	13
TN	54	55	58
PPV	0.1341	0.1358	0.1519

Table 2. Decision thresholds, statistical parameters and verification accuracy of MTseng algorithm.

Experiment	E1	E2	E3
Sg	0.1813	0.0042	0.1525
EER (%)	32	32	32
TP	17	17	16
FP	40	39	40
FN	8	8	9
TN	85	86	85
PPV	0.2982	0.3036	0.2857

3.4 Comparative Analysis of Results

Based on the numerical values shown in Table 1 and Table 2, it is concluded that the accuracy of signature verification of MTseng algorithm in relation to MTseng algorithm, for signatures: a) without normalization is higher PPV_{TSENG} / PPV_{MTSENG} = 0.2982 / 0.1341 = 2.2237 times, b) with normalization higher

PPV_{TSENG} / PPV_{MTSENG} = 0.3036 / 0.1358 = 2.2356 times, with equalization by mean value higher PPV_{TSENG} / PPV_{MTSENG} = 0.2857 / 0.1519 = 1.8808 times.

Based on the conducted analysis, it can be concluded that the modified MTseng algorithm has higher verification accuracy compared to the TSENG algorithm.

4. CONCLUSION

The Tseng signature verification algorithm is presented in this paper. After that, the MTseng algorithm, which was created by the authors by modifying the Tseng algorithm, was presented. The accuracy verification of Tseng and MTseng algorithms was determined by experiments. PPV (Positive Predictive Value) was used as a measure of accuracy verification. Comparative analysis of the results for PPV showed higher accuracy verification of the MTseng algorithm compared to the Tseng algorithm: a) 2.2237 times (without normalization), b) 2.2356 times (with normalization) and c) 1.8808 times (equalization by mean).

REFERENCE

[1] M. Fayyaz, M. Saffar, M. Sabokrou, *Online Signature Verification Based on Feature Representation*, International Symposium on Artifical Intelligence and Signal Processing (AISP), pp. 211-216, 2015.

[2] D. Impedovo, G. Pirlo, R. Plamondon, *Handwritten Signature Verification: New Advancements and Open Issues*, in Frontiers in Handwriting Recognition (ICFHR), 2012 International Conference, pp. 367-372. 2012.

[3] G. Dimauro, S. Impedovo, M. Lucchese, R. Modugno G. Pirlo, *Recent Advancements in Automatic Signature Verification*, Proceedings of the 9th Int. Workshop on Frontiers in Handwriting Recognition (IWFHR-9), 2004.

[4] G. Pirlo, *Algorithms for Signature Verification*, Fundamentals in Handwriting Recognition, ed. S. Impedovo, Springer Verlag, Berlin, pp. 433-454, 1994.

[5] R. Plamondon, S. Srihari, *On-line and off-line handwriting recognition: A Comprehensive Survey*, IEEE T-PAMI, , Vol. 22, no. 1, pp. 63-84, 2000.

[6] B. Wirtz, *Technical Evaluation of Biometric Systems*, Proc. of ACCU ’98, Hong Kong, 1998.

[7] R. Plamondon, G. Lorette, *Automatic signature verification and writer identification: The state of the art*, Pattern Recog. Vol. 22, no. 2, pp. 107-131, 1989.

[8] F. Leclerc, R. Plamondon, *Automatic signature verification: The state of the art 1989-1993*, IJPRAI, Vol. 8, no. 3, pp. 643-660, 1994.

[9] M. Faundez-Zanuy, *On-line signature recognition based on VQ-DTW*, Pattern Recognition, vol. 40, pp. 981-992, 2007.

[10] C. Higgins and D. Ford, *Stylus driven interfaces-The electronic paper concept*, Proc. ICDAR, pp. 853-862, 1991.

[11] S. Rashidi, A. Fallah, F. Towhidkhah, *Authentication based on signature verification using position, velocity, acceleration and jerk signals*, in Information Security and Cryptology (ISCISC), pp. 26-31, 2012.

[12] S. Impedovo, L. Ottaviano, S. Occhinegro, *Optical character recognition - A survey*, IJPRAI, Vol. 5, no. 1-2, pp. 1-24, 1991.

[13] Y. Jia, L. Huang, H. Chen, *A Two-Stage Method for Online Signature Verification Using Shape Contexts and Function Features*, Sensor, Vol. 19, pp. 1808, 2019.

[14] Chien-Cheng Tseng, *Design of variable and adaptive fractional order FIR differentiators*, Signal Processing, Vol. 86 pp. 2554–2566, 2006.