Stability of a dynamic biometric signature created on various devices

Vladimír Smejkal
Department of Informatics
Faculty of Business and Management
Brno University of Technology
Brno, Czech Republic
smejkal@znalci.cz

Jindřich Kodl
Authorized expert of cryptology and information systems security
Prague, Czech Republic
jm.kodl@gmail.com

Ladislav Sieger
Department of Physics
Faculty of Electrical Engineering
Czech Technical University in Prague
Prague, Czech Republic
sieger@fel.cvut.cz

František Hortai
Department of Informatics
Faculty of Business and Management
Brno University of Technology
Brno, Czech Republic
hortai.frantisek@gmail.com

Petr Tesař
Department of Informatics and Mathematics
Faculty of Economic Studies
University of Finance and Administration
Prague, Czech Republic
petr.tesar@post.cz

***Abstract*—The paper directly follows on from the prior research on the dynamic biometric signature (DBS), its properties, security, its resistance to forgery, and its stability. In our experiments, we used all the available pads produced by Signotec, which differ from each other in terms of their design, the size of the signature field, resolution, sampling rate, and even the scanning method used – a regular pen or a special pen using the ERT (Electromagnetic Resonance Technology). A less heterogenous sample was used than in the previous cases, as the objective of the experiments was to demonstrate a potential change in the DBS connected with the use of a different device, nevertheless the size of the sample means it is sufficiently statistically representative.**

The results showed that irrespective of the device used, the stability of scanning of the dynamic biometric signature was high for each person. The signature variability did not significantly differ between the devices for individual people.

Once again it was confirmed that the use of the first signature as a "trial", not included in the results, reduces the signature variability for each participant.

Keywords—dynamic biometric signature; biometric data of the signature; stability of the dynamic biometric signature; dynamic biometric signature capture device

I. Introduction

The dynamic biometric signature is increasingly being implemented primarily in such application areas as financial services, healthcare and public administration. Its importance grows due to the increasing demands on the trust in authenticity of the signature and authentication of the person signing in a digital environment. Last but not least, it is the dynamic character of the method that significantly reduces the possibility of identity theft, or forgery of the authentication factor by another person.

The presented results of our initial research continually follow those of our earlier papers published within the ICCST conference. Issues of the indisputable connection of the created DBS with the text of the electronic document that is being signed were investigated in our previous ICCST papers [1], [2]. We also performed basic experiments demonstrating the uniqueness of the DBS and its resistance to forgery [3].

In addition to confirming the uniqueness of the DBS, its stability is another crucial aspect. That is why, in 2015, we dealt with the impact of alcohol on the stability of the dynamic biometric signature in a more homogeneous group as well as the uniqueness and resistance of the signature to forgery in a highly heterogeneous group of people aged 12 to 92 [4]. In 2016, we presented a report on the impact of stress on the stability of the dynamic biometric signature [5].

So far, we have dealt with the changes relating to a signer or the influences of his surrounding on the signing situation, in which case the used equipment was always the same, i.e. invariant. Therefore, we were now interested whether there was an impact of using different scanning devices by the same person on the quality of data and stability of the DBS and, alternatively, what this impact was. Our paper describes the experiments that were related to the impact of using various devices (pads and tablets) on the dynamic biometric signatures of a particular person. The obtained results continually follow those of our earlier published papers.

In our experiments, we used all the available pads produced by Signotec, which differ from each other in terms of their design, the size of the signature field, resolution, sampling rate, and even the scanning method used – a regular pen or a special

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pen using the ERT (Electromagnetic Resonance Technology). The purpose of the experiments was to show the possible change of the stability of the DBS of a signer depending on the scanning device. As the sample represented people of both sexes aged 20 to 65, the size of the heterogeneous sample used was statistically representative enough.

II. HYPOTHESES

The following hypotheses were formulated:

I. The participants will cope with the difficulties connected with changing circumstances of the signing depending on the technical design of the pad in a different way:

H_0 – the stability of signatures of a particular person on each device does not significantly change (mean and variance of the degree of compliance of signatures for each device belong to the same basic set),

H_1 – there is a statistically significant difference in the means and variances of the degree of compliance of signatures of a particular person on individual devices.

II. The stability of signatures achieved on individual devices will statistically significantly differ.

H_0 – the mean degree and variance of compliance of signatures for each device do not significantly change (mean and variance of the degree of compliance of signatures for each device belong to the same basic set),

H_1 – there is a statistically significant difference in the means and variances of the degree of compliance of signatures on individual devices.

III. METHODS AND DATA

Testing was carried out on the following dynamic biometric signature devices with the various technical parameters produced by the company Signotec GmbH in the last five years:

TABLE I. OVERVIEW OF THE TESTED DEVICES

Method of the signature capture	**Model of the dynamic biometric signature device**
The active pen, display, and pen are mutually synchronized	**Signotec Alpha Pad (hereinafter referred to as Alpha – ERT)** ST-A4E-2-UFTE100: Colour LCD Signature Pad Alpha ERT (Electromagnetic Resonance Technology) https://en.signotec.com/portal/seiten/a4-colour-lcd-signature-pad-signotec-alpha-900000330-10002.html?rubrik=900000001
The display is electromagnetic, the pressure is captured on the basis of the outward pressure of the passive pen on the display	**Signotec Delta Pad (hereinafter referred to as Delta – ERT)** Touch display ST-DERT-3-U100 ERT (Electromagnetic Resonance Technology) https://en.signotec.com/portal/seiten/colour-lcd-signature-pad-signotec-delta-900000406-10002.html?rubrik=900000001
The display is electromagnetic, the pressure is captured on the basis of the outward pressure of the passive pen on the display	**Signotec Gamma Pad (hereinafter referred to as Gamma – ERT)** Touch display ST-GERT-3-U100: 5" Colour LCD Signature Pad Gamma ERT (Electromagnetic Resonance Technology) https://en.signotec.com/portal/seiten/colour-lcd-signature-pad-signotec-gamma-900000375-10002.html?rubrik=900000001
The display is a touch-screen, the pressure is captured on the basis of the outward pressure of the passive pen	**Signotec Omega Pad revision B (hereinafter referred to as OmegaOld – TD)** Touch display ST-CE1075-2-U100 (old version, reference is no longer available)
	Signotec Omega Pad revision E (hereinafter referred to as OmegaNew – TD) Touch display ST-CE1075-2-U100 (current version) https://en.signotec.com/portal/seiten/colour-lcd-signature-pad-signotec-omega-900000237-10002.html?rubrik=900000001
	Signotec Sigma Pad revision B (hereinafter referred to as SigmaOld – TD) Touch display ST-ME105-2-U100-B (old version)
	Signotec Sigma Pad revision E (hereinafter referred to as SigmaNew – TD) Touch display ST-ME105-2-U100-B (current version) https://en.signotec.com/portal/seiten/lcd-signature-pad-signotec-sigma-900000301-10002.html?rubrik=900000001
There is no display, only the touch area	**Signotec Sigma Lite (hereinafter referred to as SigmaLite – WD)** Touch area without a display function ST-LT105-2-U100 https://en.signotec.com/portal/seiten/signature-pad-signotec-sigma-lite-without-lcd-900000411-10002.html?rubrik=900000001

A total of 8 scanning devices were used. The sampling frequency of the used devices can be set up to 150 Hz, 250 Hz or 500 Hz. The scan rate (sampling) was set up to recommended 250 points/sec. The x, y, time and pressure coordinates are scanned. The experiment was attended by 40 people in one session.

IV. EXPERIMENTS AND RESULTS

DBS were recorded on the devices using the program signoSign2 version 10.4.5. produced by Signotec. Each participant made 10 signatures on each device, so the matrix of signatures of each participant and all devices was formed $\bar{P}_{i,j}$ as follows:

$$\bar{P}_{i,j} = [x_1, \dots, x_{10}]_{i,j} \quad (1)$$

where i is a serial number of the device, j is a serial number of the participant, x_k is a particular signature.

In accordance with the findings from the previous works ([3], [4], [5]), the first signatures made by each person on a particular device were not included in the evaluation. The signature match rate is automatically evaluated by the analytical software of device manufacturer.

A. Testing of the hypothesis I.

In the first part of the evaluation of the experiments, the degree of compliance among the signatures $\bar{x}$ of each person within each device was investigated (in %) – the output is a triangular matrix of compliances $\{s_{m,n}\}$ m=2,…8, n=m+1, where for each device the selective mean of compliance of signatures of a particular person on this device, the selective variance of compliance M_2 and the selective standard deviation σ were calculated. That is how the vector of the selective means of compliances $\bar{x}_1$ to $\bar{x}_8$, the vector of the selective variances $M_{2,1}$ to $M_{2,8}$, and the vector of the selective standard deviations σ_1 to σ_8 were obtained for each person and all the equipment.

A three-dimensional chart in Fig. 1 illustrates the obtained structure of data used to ascertain the selective standard deviation of the degree of compliance among the signatures (2 numbers of people are not assigned – No. 6 and No. 23):

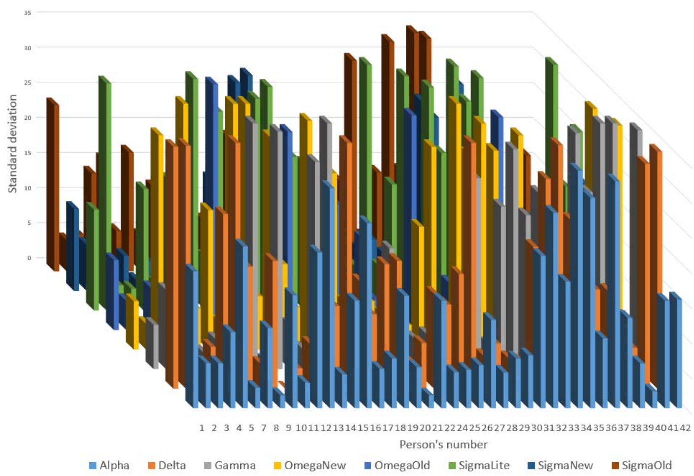

Fig. 1. Selective standard deviation of the degree of compliance

The result characterizing the technology as a whole, i.e. without differentiation of types of devices and signers (i.e. for all people on all devices) is as follows:

TABLE II. SUMMARY RESULTS ON THE DEGREE OF COMPLIANCE OF SIGNATURES

x [%]	M_2	σ [%]
79.330	173.290	13.164

The selective mean of the degree of compliance of signatures came under an accepted level of compliance of biometric signatures ≥ 60% only in case of two people (No. 16 and No. 34) – see Fig. 2:

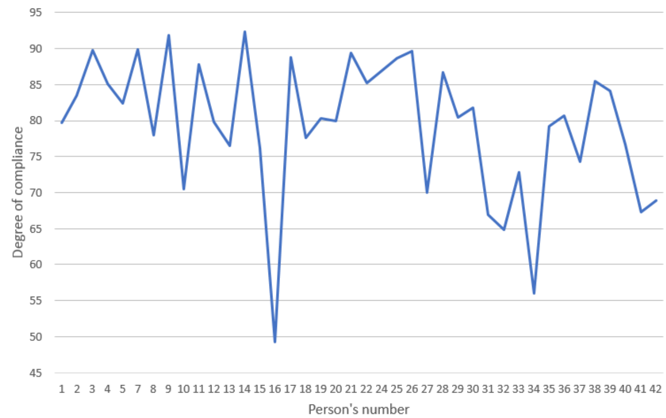

Fig. 2. Selective mean of the degree of compliance for individual people

It is assumed that independent random selections originate from normal distributions with mean values μ_1, μ_2 …. μ_r with the same variance σ^2.

In order to test the homogeneity of variances of the degree of compliance of signatures of each participant on all devices, the Bartlett's test was used [6]. The values in the B test ranged from 20.341 to 609.934, i.e. the P-value was between 0.000 and 0.005. For all participants, the null hypothesis was therefore rejected at the significance level 0.01 and thus at the significance level 0.05 (as the P-value was <0.01 for all participants).

Using the Cochran-Cox test [7], a pair of devices, where the hypothesis on compliance of means of the degree of compliance was rejected at the significance level 0.01, was found for each participant. The simple sorting test (analysis of variance, ANOVA) that would keep the probability of error of the first kind at the level 0.05 or 0.01 could not be used with regard to the results of the Bartlett's test.

Due to the facts that selective variances of the degree of compliance are significantly different for all participants on individual devices and there are differences in means of compliances, we can conclude that the participants coped badly with various designs of devices.

B. Testing of the hypothesis II.

The following values of selective means and unbiased estimates for variances of the degree of compliance of signatures were detected on the stated devices:

TABLE III. SELECTIVE MEANS AND UNBIASED ESTIMATES FOR VARIANCES OF THE DEGREE OF COMPLIANCE OF SIGNATURES ON THE TESTED DEVICES

Device and scanning method	**x [%]**	**S^2**
Alpha - ERT	80.342	113.019
Delta - ERT	76.749	238.268
Gamma - ERT	78.971	232.027
OmegaNew - TD	76.022	228.052
OmegaOld - TD	83.002	125.844
SigmaLite - WD	77.097	148.574
SigmaNew - TD	85.233	139.194
SigmaOld - TD	77.195	120.338

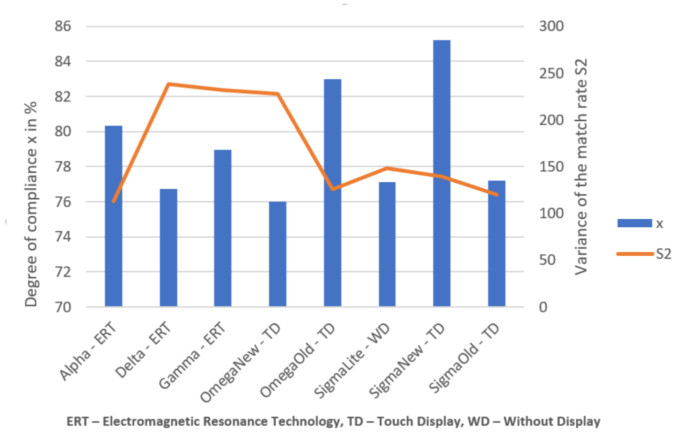

Fig. 3. Selective means and unbiased estimates for variances of the degree of compliance of signatures on individual devices

Compliance of variances was verified by the Bartlett's test (B = 13.597, k-1 = 7, α = 0.01 and 0.05, P-value = 0.059), so the hypothesis on compliance of all variances was accepted at the significance level 0.01 and at the significance level 0.05.

The simple sorting test (ANOVA) [7] gave the following results F = 2.565, k = 7, n-k = 306, P-value = 0.014, α = 0.01 and 0.05, $F_{0.01}$= 2.700 and $F_{0.05}$= 2.039, where $F_{1-\alpha}$(k-1, n-k) is (1-α) quantile of the Fisher-Snedecor distribution for the significance level α, so compliance of all means was accepted at the significance level 0.01 and rejected at the significance level 0.05.

The results of the Scheffe's test of multiple comparisons [8] would enable to determine between which two above-mentioned means the statistically significant differences exist. The Scheffe's test accepts the equality of all 28 pairs of means of the degree of compliance of signatures at the significance level 0.01 and 0.05 (28 is the number of possible options for all pairs of devices).

When using different devices, there were found no differences between the mean values of the degree of compliance (x) and values of variance of the degree of compliance (σ^2), that is at the significance level 0.05 for variances and at the significance level 0.01 for means. It can therefore be noted that, despite the technological differences among individual devices, the stability of signatures (indicated by variance) does not change when changing the device. Also, the degree of compliance of signatures on all devices does not statistically significantly differ at the significance level 0.01.

V. DISCUSSION

The results showed that the mean degree of compliance is high for individual people (it fell below 60% only in case of 2 people), but the selective variances of the degree of compliance are significantly different for all participants on each od all used devices, which means that the participants coped badly with various designs of devices. This follows from the fact that the DBS is a highly automated activity given by an acquired stereotype. The different design of the pad (thick pen, non-displayable signature, small signature area, hand resting beyond the pad, etc.) can lead to the distortion of the stereotype and higher variance between the signatures.

By contrast, regardless of the individual properties of the signers, the mean values of compliance of signatures of all people on all devices were high (from 76 to 85) and there were no differences between the values of means and variances of the degree of compliance when using different devices, that is at the significance level 0.05 for variances and at the significance level 0.01 for means.

The different scanning technology does not affect the degree of compliance and variability of signatures – see Fig. 3 above. In the opinion of the authors, the "user-friendliness" is a key factor in creating the signature. Another factor is then the individual characteristics of the signer. The variability of the signature, and hence the low degree of compliance among individual signatures, which is exceptionally manifested among the signers, is closely related to the stability of the signature. The greater the intra-personal variability is, the less stable the signer is. [9] There are two types of the variability of signatures: the short-term (depends on the psychological state of the person and on the conditions of writing) and the long-term variability (depends on the change of the system of physical writing, or modification of the motor program in the brain) [10] – e.g. due to the influence of the disease or aging. According to our experiments, where instead of the optical evaluation of the signature images the biometric characteristics were analyzed, it was however proved that the influence of external factors on the short-term variability is negligible [2], [3], [4], [5].

In our paper, we describe experiments that related to the influence of different devices (pads) on the DBS performed by the signing person. An interesting contribution to this issue is a paper [11] dealing with the creation of DBS database in relation to variable devices (pads)

Our experiments used pads when DBP was verified using time functions (X, Y, Z coordinates etc.), that we consider to be most reliable today. Here, it will be suitable to focus on other evaluation algorithms (see [12]), as more and more types of signing devices are currently being used.

In our experiments, we have confirmed the stability of the DBS in the changing environment surrounding the signing persons. The results of the experiments are consistent with the papers [13], [14] where DBS stability models are proposed with regards to the significant aspects of the signature, respectively, to the behaviour of the signers.

We have dealt with the changes relating to a signer or the influences of his surrounding on the signing situation. However, the impact of the aging of the signer has not been included in these experiments, as long-term results have to be taken into account. Modelling aging issues [15] deals with the design of time-based systems such as the Hidden Markov Model (HMM), in which case the results of the studies will be confirmed experimentally, which is also the subject of our future work.

VI. Conclusion

Hypothesis I. – The participants will cope with the difficulties connected with changing circumstances of the signing depending on the technical design of the pad in a different way: The null hypothesis H0 claiming that the stability of signatures of a particular person on each device does not significantly change, that is at the significance level 0.01 and thus at the significance level 0.05, was disproved. A pair of devices, where the hypothesis on compliance of means of the degree of compliance was rejected at the significance level 0.01, was found for each participant. Therefore, the hypothesis H1 claiming that there is a statistically significant difference in the means and variances of the degree of compliance of signatures of a particular person on individual devices was confirmed.

Hypothesis II. – The stability of signatures achieved on individual devices will statistically significantly differ: The null hypothesis H_0 claiming that the mean degree and variance of compliance of signatures for each device do not significantly change, because there were found no differences between the values of means and variances of the degree of compliance when using different devices, that is at the significance level 0.05 for variances and at the significance level 0.01 for means, was confirmed.

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