Biometric electronic signatures as the new object of handwriting examination

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Summary

Analyses of electronic biometric signatures constitute an innovation in forensics. The aim of the study described in this article was to determine whether it is possible to categorically confirm or exclude both the authenticity and the execution of handwritten biometric electronic signatures. Several-year-long research on various types of electronic signatures has made it possible to formulate categorical conclusions in this area. The article defines and determines the terminological scope of the biometric electronic signature concept within the widely understood electronic signatures. The analyses of biometric signatures were based on the graphical-comparative method commonly used in the traditional model of handwriting analysis. The only modification consisted in replacing the set of motoric features with biometric features, which turned out to be necessary for a categorical opinion on this matter. Study results described in the text allow for quantitative examination within analysis of manuscripts thus enabling issuing a categorical opinion. The biometric features of handwriting identified entirely by means of digital data ought to contribute to the elimination of any bias that might exist on the part of an expert.

Key words: biometry, signature, forensic science, expert opinion, graphical-comparative method

Introduction

Analysis of signatures constitutes one of the most difficult areas of handwriting opinions. The assessment of the characteristics indicated in a signature is not easy and the interpretation of observed conformities and differences between the evidence and comparative material comprises a margin of expert subjectivity.

Biometric electronic signatures being the subject of this article are described entirely with numbers and that helps to eliminate the element of subjectivism in their assessment by an expert. An overview of the latest IT technologies for companies and institutions operating, among others, in the area of postal, courier, banking, insurance and telecommunications services indicates the growing popularity of electronic biometric signatures, which are referred to as the future or simply as an indispensable element of contemporary organisations.

Definition of biometry and determining the purpose of its use

The word "biometry" derives from Greek words *bios* – life and *metron* – measurement. Originally, it was understood as measuring the characteristics of living creatures without indicating the purpose and method of performing the measurement. Currently, the literature of the subject emphasises that the purpose of using biometry is automatic authentication of identity which can be divided into two categories:

– confirmation (verification) of identity;
– establishing (determination) of identity (Marucha-Jaworska, 2015, p. 169).

Identity is verified or determined on the basis of its physiological or behavioural characteristics referred to as biometrics. Physiological biometrics carry information related to physical characteristics. They are static in nature and can be measured (read) at any time. The categories of physiological biometrics include: facial image, fingerprints, hand geometry, image of the iris and the retina of the eye, DNA, ear shape, smell, pattern of blood vessels in the finger and hand, skin reflection. On the other hand, the essence of behavioural characteristics is the manner of performing a given activity. They are dynamic and last over a period of time that is needed to measure or observe them. Behavioural characteristics can be acquired or learned, or they may be genetically determined. The behavioural biometrics category includes: execution of a handwritten signature, speed of typing, way of typing, mouse movement, voice, mouth movement, manner of walking, the course of brain reaction (Czajka, Pacut, 2004). The mentioned physiological and behavioural biometrics can be used in the automatic identification and verification of persons, however, in practice the following are currently taken into account: fingerprints, the arrangement of blood vessels of the finger, hand or wrist, hand and face geometry, the iris of the eye, handwritten signature and the method of its execution.

Terminology within the concept of electronic signature

The definition and determination of the terminological scope of biometric electronic signature concept requires clarifying its place in the general structure of electronic signatures.

The law does not regulate the form of electronic signature and that results in the variety of electronic services being in use. In Directive 1999/93/EC of the European Parliament and of the Council of 13 December 1999 on a Community framework for electronic signatures[1], the electronic signature is defined as "data in electronic form which are attached to or logically associated with other electronic data and which serve as a method of authentication". In addition, the term "advanced electronic signature" has also been introduced, which complies with the legal requirements for electronic data in the same way as a handwritten signature for data on paper.

In Poland, the provisions of the above-mentioned Directive were implemented by the Act of September 18, 2001 on electronic signature[2]. The act introduced a qualified electronic signature into Polish law, which, despite its announcement, did not achieve great success.

It is used mainly in the structures of public and local government administration and, rarely, by individual legal entities. On the other hand, a handwritten biometric signature has been used in everyday life and is used, for example, to confirm receipt of a parcel or to conclude a telecommunications contract. They have been implemented by small companies and individual entities.

In connection with the use of a handwritten biometric signature, it is worth emphasising that the Act of September 5, 2016 on trust services and electronic identification[3] and the Regulation (EU) No 910/2014 of the European Parliament and of the Council of 23 July 2014 on electronic identification and trust services for electronic transactions in the internal market[4] are currently in force in Poland. These laws allowed for the implementation and authentication of digital documents using both solutions, i.e. cryptographic and biometric security. With regard to the security measures used, it is commonly defined as "digital signature" / "electronic signature". A cryptographic digital signature (qualified electronic signature) is an object of examination by experts in the field of computer science. Its use requires the a certificate issued by a qualified certification authority and a private key stored on a cryptographic card. A qualified electronic signature is legally equivalent to a handwritten signature, however, it is created without the use of the signatory's hand. The biometric electronic signature in literature, especially in Internet resources, is also referred to as: "biometric signature", "handwritten electronic signature", "handwritten biometric signature". The idea behind this signature is based on the principle of individual handwriting.

A biometric signature is a handwritten signature placed on a dedicated device, usually a tablet, using a special stylus. Such a signature does not have a graphic line as in a traditional signature, but it is made of hundreds of points written at the shortest intervals possible. Each point is assigned a value of time, pressure and location in the x, y coordinate system. The advantage of authenticating a document with a biometric signature is its handwritten form, enriched with graphic features and non-obvious biometric features recorded during drawing. In addition to that, such a document is secured, among others RSA private key technology (Rivest-Shamir-Adleman Algorithm). This signature is inseparably inscribed in a digital document, and any interference in its structure makes it impossible to decrypt it.

Examination of the characteristics of biometric signatures

The properties of the biometric electronic signature allow them to be examined using the graphical comparative method used in the traditional model of literary analysis. However, due to the greater range of biometric signatures features, the indicated method can be extended with the analysis of additional properties that significantly increase the examination potential.

In the classical approach the graphical-comparative method is based on the analysis of graphical features classified in a set of synthetic, topographic, motor, measurable and constructional features. The found similarities and differences between the compared materials are in each case considered individually taking into account examination values of individual features.

Due to the scope of the analysed biometric features, it is justified to pay attention to the set of motoric features, which in the case of classic studies include the rate (speed) of writing, determined

– in an absolute way: small, medium, large;
– as part of a handwriting sample (constant, variable);
– in relation to the personal norm (slow, natural and accelerated).

The pace of writing is a manifestation of motoric skills most sensitive to changes – both conscious, aimed at masking the features of one's own handwriting and those resulting from the individual's development. Within a set of motoric features also comparisons of the impulse of writing defined as the frequency of detachment of the writing tool from the background, pressure and the associated shading of the graphic line (which in the light of the subject matter discussed in the article seems to be very important) are made. Detailed analysis allows to evaluate the following:

1 Official Journal of the EU L 13 of 19.01.2000, pp. 12–20.
2 Journal of Laws of 2001 no 130, item 1450, as amended.
3 Journal of Laws of 2016, item 1579, as amended.
4 Official Journal of the EU L 257 of 28.08.2014, pp. 73–114.

– pressure direction, which can be ascending, descending, right or left;
– pressing force as low, medium or high;
– uniformity of pressure – constant or variable, rhythmic or non-rhythmic;
– places of increased pressure, e.g. designated in the upper elements of the characters.

It is worth recalling that already W. Wójcik paid special attention to the beginnings and endings of written lines. He argued that the way the tip of the writing implement touches the background and is taken off it are not the same for two people. Usually, they differ in the pressure of the hand and in the direction of contact of the implement with the background (Wójcik, 1971, p. 56). The special value of this feature was also indicated by Z. Czeczot who distinguished the emphasis of writing as a separate group located on the border of measurable and descriptive features (Czeczot, 1971, p. 116). In the set of motoric features the sequence of graphic elements is also distinguished, i.e. the order of writing elements within characters (letters or numbers) and within a sequence of characters. It should be remembered to distinguish between the concepts of sequence of motion and sequence of signs, as they are not identical. The phenomenon of the sequence of movements, also known as the chronology of hand movements, mainly refers to diacritic and supplementary signs and concerns the habitual order of their making. It allows you to recreate the hand movements performed during the writing activity. On the other hand, the sequence of characters is the use of one of the variants or varieties of signs depending on their location in a word or the position in the vicinity of a specific letter.

In the study of biometric signatures the set of motor features was enriched with measurable biometry records that extend the examination potential, and narrow the likely area of the expert's subjectivism. Biometric data expressed in a numeric form also allow the use of statistical calculations, including the average pressure values for a signature or a group of signatures, average writing speed, and determining the maximum and minimum pressure in particular fragments.

A biometric signature as the object of identification examinations

Due to the lack of an unequivocal definition of the form of an electronic signature it has become the object of examinations in criminal proceedings. More and more inquiries as to the possibility of executing analyses of these signatures have been directed to the police forensic laboratories. This has become a reason for the Central Forensic Laboratory of the Police (CFLP) undertaking research on a biometric signature as regards the identification potential. During international conferences attended by CFLP experts results of expert examinations research in the field of handwritten electronic signature were presented several times. However, there have been no scientific reports on the possibility of issuing opinions on biometric signatures. Therefore, the analyses carried out in CFLP aimed to answer the following questions:
– Is it possible to confirm the executive homogeneity of signatures on paper and biometric electronic signatures?
– Is it possible to imitate signatures while maintaining the similarity of biometric and graphic features?
– Can a "perfect" forgery be achieved?
– What examination method should be used and what type of comparative material should be collected in order to provide opinions on biometric electronic signatures?
– What inference possibilities will the analysis of electronic signatures with a biometric layer bring?

At this point, it should be mentioned that there are signature creation devices in common use which do not record the biometric layer. In this case a possible questioned signature is submitted for examination in a form of a printout of its image, which, due to its examination limitations, is not the object of identification. However, when we are dealing with a device that also records the biometric data of the signature placed on it, the examination possibilities are entirely different.

The most important element when signing on an electronic device is the requirement that the entire process should reflect the flow of traditional writing. It is not a question of the application itself, but also of the quality of the device on which the signature is made. Currently, manufacturers offer devices of increasingly better quality. Many devices designed directly for creating and saving biometric signatures have been also made available on the Polish and global market. More and more entities are using such devices, which should be considered a positive trend. In addition, it is worth noting that the biometric signature is permanently assigned to a specific document, and any change or interference in the document is either saved or causes the signature to be rejected as invalid.

From the point of view of an expert in the field of handwriting examination the best devices and applications used to authenticate documents with a biometric signature are those that simultaneously register:
– graphic image of the signature,
– time of signing and including all its elements,
– the pressure of the stylus on the tablet screen,
– the location of the points building the signature in relation to the *x*, *y* axes,
– adjustments, i.e. the movements of the stylus above the tablet.

Form and scope of the examinations undertaken in CFLP

In the two-year-long study carried out at CFLP, the research material consisted of biometric signatures collected over various periods in time from persons with different education and ages. One thousand five hundred electronic signatures with biometric layers of various structures from the simplest to complex legible forms were analysed. A tablet with a stylus enabling the recording of biometric data were used. During the research, a generally available application for signing digital documents was applied as well as software employed in one of the entities in the postal service. The tablet, which was used during the tests, has special sensors on the screen, covered with a dense grid of points sensitive to the change of electromagnetic voltage exerted by the stylus. It also includes x- and y-axis sensors that act on the resonance circuit in the stylus. The electromagnetic technology applied in the tablet recognises up to 4096 levels of pressure, which, in turn, allows for very precise measurements[5].

During the research carried out at CFLP, attempts were made to forge authentic signatures by means of learned and visual imitation and copying through a sheet of paper with the use of the above-mentioned tablet.

It should be mentioned that the analysed applications allow saving signatures made in a digital PDF document or directly in another file, e.g. XML. The signature is handwritten, but not on a paper substrate, as before, but on a tablet screen with a biometric layer. The writing tool has a shape similar to that of a pen. The only change is the stylus tip, which in this case allows the use of electromagnetic technology. As a result, when signing a document on the tablet, in addition to the image of the signature, biometric data are saved, which constitute the basis for issuing opinions on handwritten electronic signatures. Upon completion of the study the researchers came up with a set of biometric features which constitute an extension of the motoric features used so far.

Assessment of biometric electronic signature examination value

The analysis of the research possibilities of a biometric signature should begin with the parameter, to which the others are related, namely the position of individual signature points in relation to the *x* and *y* axes. The record of these densely located and then connected points provides an image of the biometric signature. Therefore, it can be concluded that the analysed feature is an image of the signature, but saved in a numerical form. Both an application for biometric signatures and a traditional Excel sheet were used to analyse the positions of the points. The Excel sheet made it possible to represent the signature in various ways in the coordinate system with the *x* and *y* axes. On the other hand, the application itself allowed visualising the position location of a point on the *x* or *y* axis with respect to time, and creating repetitive lines on the plot. Figures 1–3 present the image of the authentic signatures of the respondents in the biometric analysis application and in the Excel sheet.

Specifying the location of individual signature points in the *x, y* coordinate system also allows determining the direction and sequence of writing individual characters and their elements. Figure 4 presents a signature in the form of a plot with marked points positioned in the *x, y* coordinate system. Figure 5 shows the sequence of drawing the signature elements determined on that basis.

The ability to analyse the implementation time of a biometric signature, its individual parts and characters is a very important element of the research. In the traditional model of handwriting analysis it is relatively determined whether the signature was created at a constant or variable, small, medium or high, slow, natural or accelerated speed (Koziczak, 1997, p. 41). It is extremely important that the signing process on the tablet is registered. The course of the signature execution can be reproduced as in a video, thanks to which it is possible to analyse the speed of drawing the components of the signature and moments of pondering or hesitation during its drawing can be observed. An important parameter is the time between touching the tablet screen with the stylus, e.g. between writing individual parts of the signature, successive characters or their construction elements (grammas). In imitated signatures the intervals are longer, as compared to the authentic signatures. This is due to the fact that a counterfeiter focuses only on the best graphic representation of the signature image, not paying attention to the elapsed time.

Figure 6 presents an authentic and imitated signature with a visible difference in times their execution. The difference also concerns the time interval between signature writing and the visible supplementary element (gramma).

Another feature that is recorded when placing a biometric signature is pressure. Although no exceptional significance is attributed to any of the features within the graphical-comparative method used to analyse entries made on paper background, pressure is undoubtedly among the important ones. The pressure on the paper substrate is assessed by the depth of grooves and reliefs left by the writing tool as well as the degree of saturation of paper with the writing medium, e.g. ballpoint pen ink. Nevertheless, it is often difficult to judge where the pressure is greatest and where it is the smallest. With regard to biometric

[5] *Samsung Galaxy Tab S3 – test tabletu z rysikiem. Tak wyglądałby iPad Pro z Androidem*, https://www.tabletmaniak.pl/232878/samsung-galaxy-tab-s3-test/ (accessed on: 15.04.2020); *Tajemnica rysika Samsunga Galaxy Note*, https://www.tabletowo.pl/tajemnica-rysika-samsunga-galaxy-note/ (accessed on: 15.04.2020).

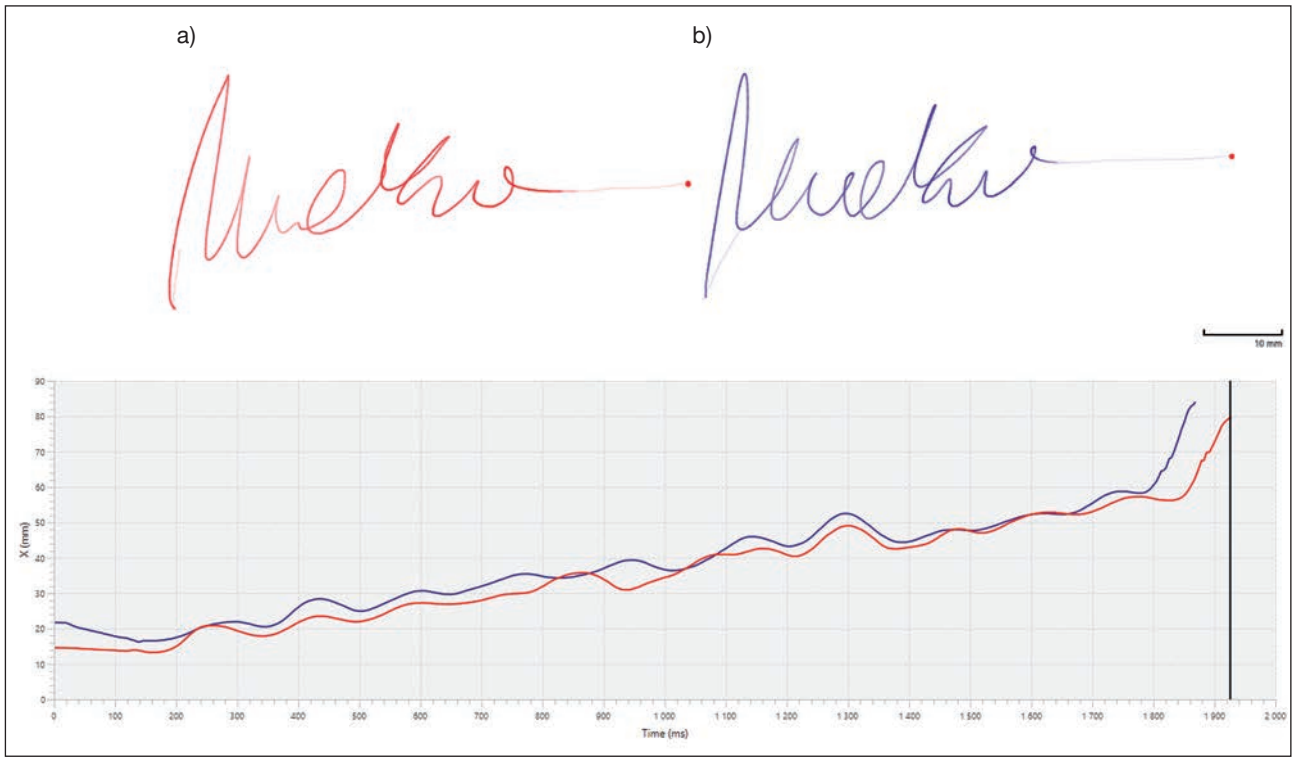

Fig. 1. Plot of recorded *x* coordinates in relation to time.

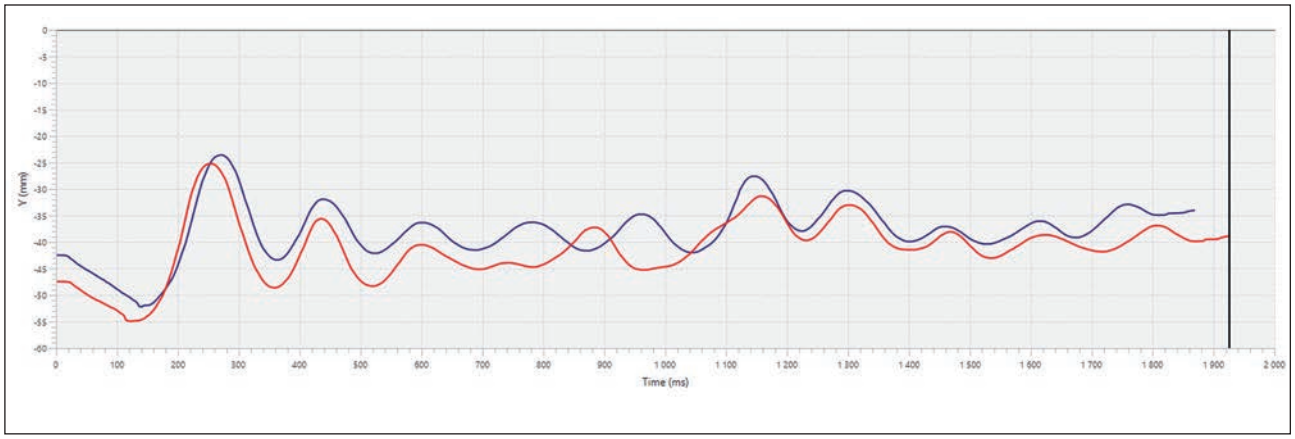

Fig. 2. Plot of the recorded *y* coordinates in relation to time.

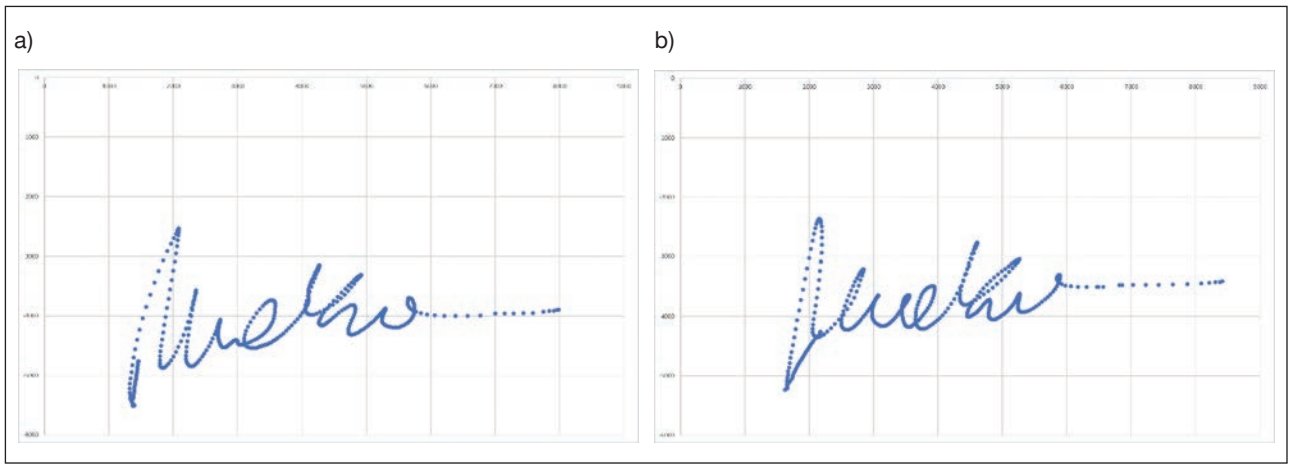

Fig. 3. Plots of authentic signatures in coordinate system.

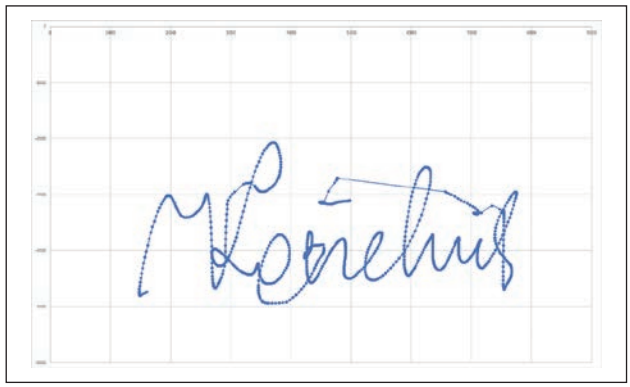

Fig. 4. Plot of a signature in the *x, y* coordinate system.

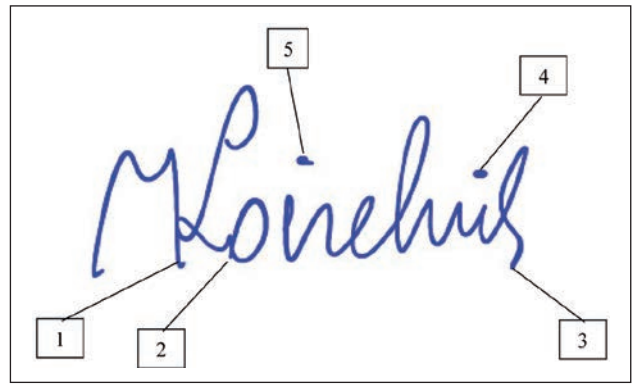

Fig. 5. A signature with identified sequence of element execution.

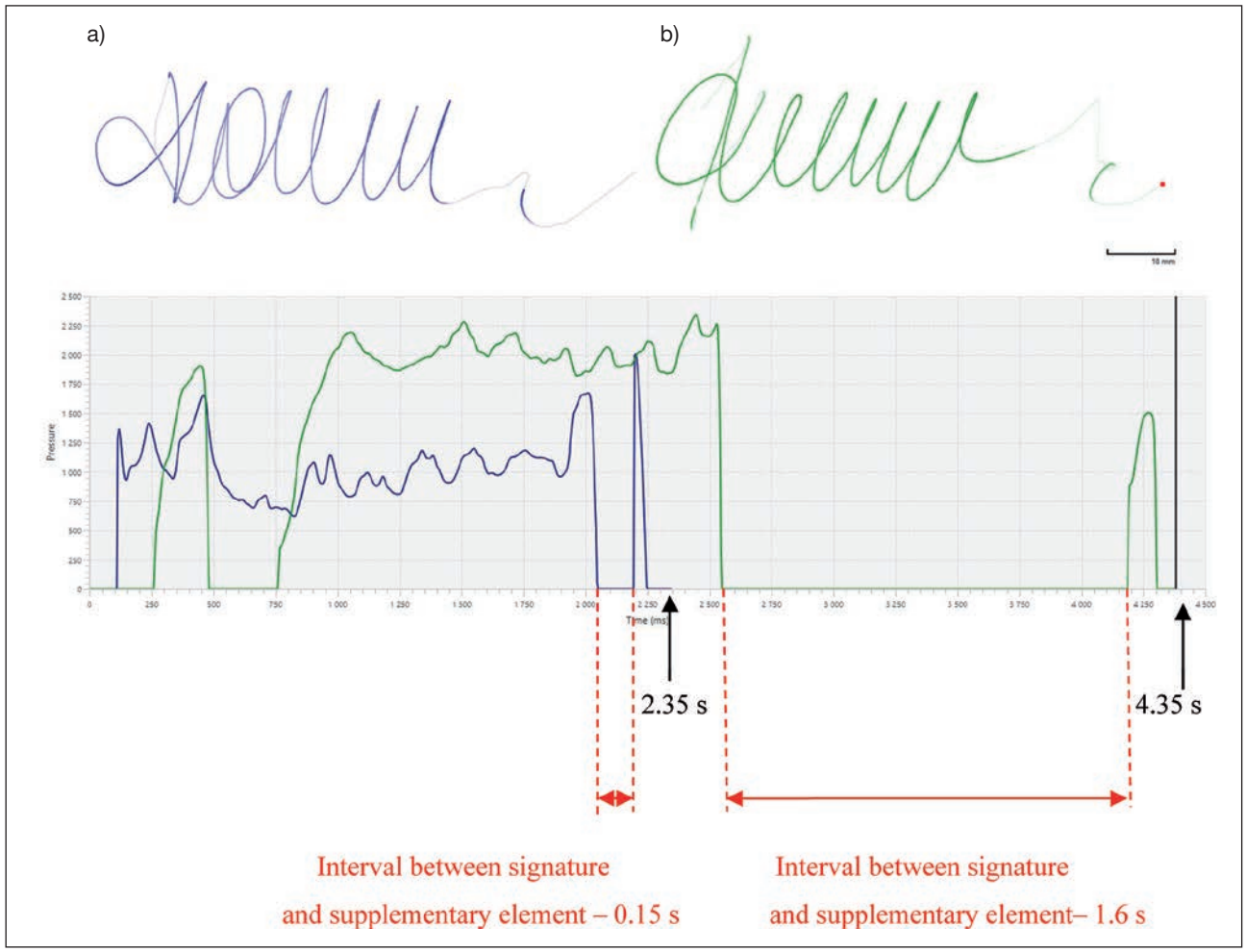

Fig. 6. Time of signature execution: (a) authentic signature, (b) imitated signature.

signatures the assessment of this parameter through the form of its recording is unambiguous. A comparative analysis of the pressure in biometric signatures allowed for the conclusion that it is a highly individualised feature characterising each person's signature. The analysis of pressure in biometric signatures makes it possible to determine the natural manner of their execution and refer to it. In the case of authentic and automated signatures the pressure is fluent and, at the same time, diverse, while in the case of imitated signatures – unrepeatable, irregular and of low variability.

Figures 7–9 present plots of pressure in the authentic and imitated signatures.

It is possible to calculate the average pressure of individual signatures of a given person or the average pressure of several signatures based on statistical

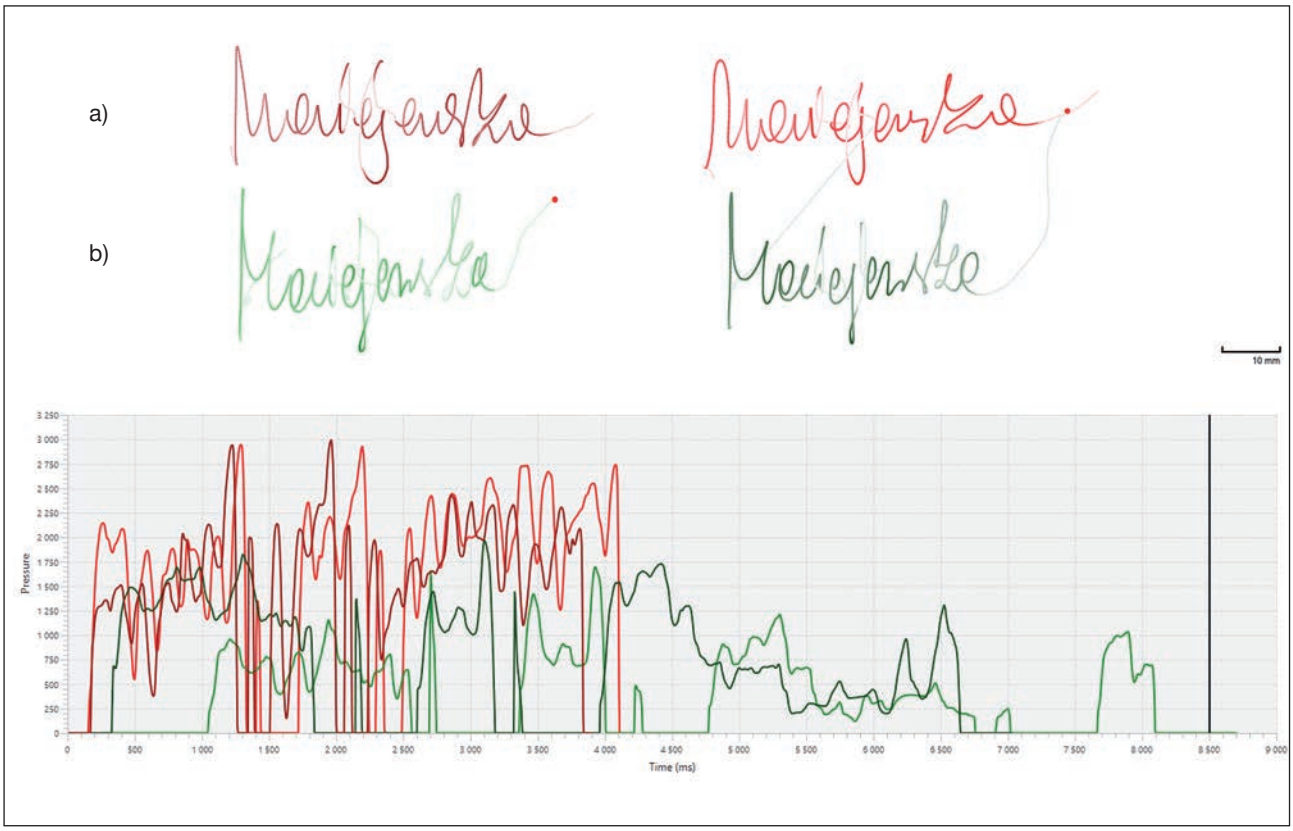

Fig. 7. Pressure in authentic signatures (a) and imitated signatures (b).

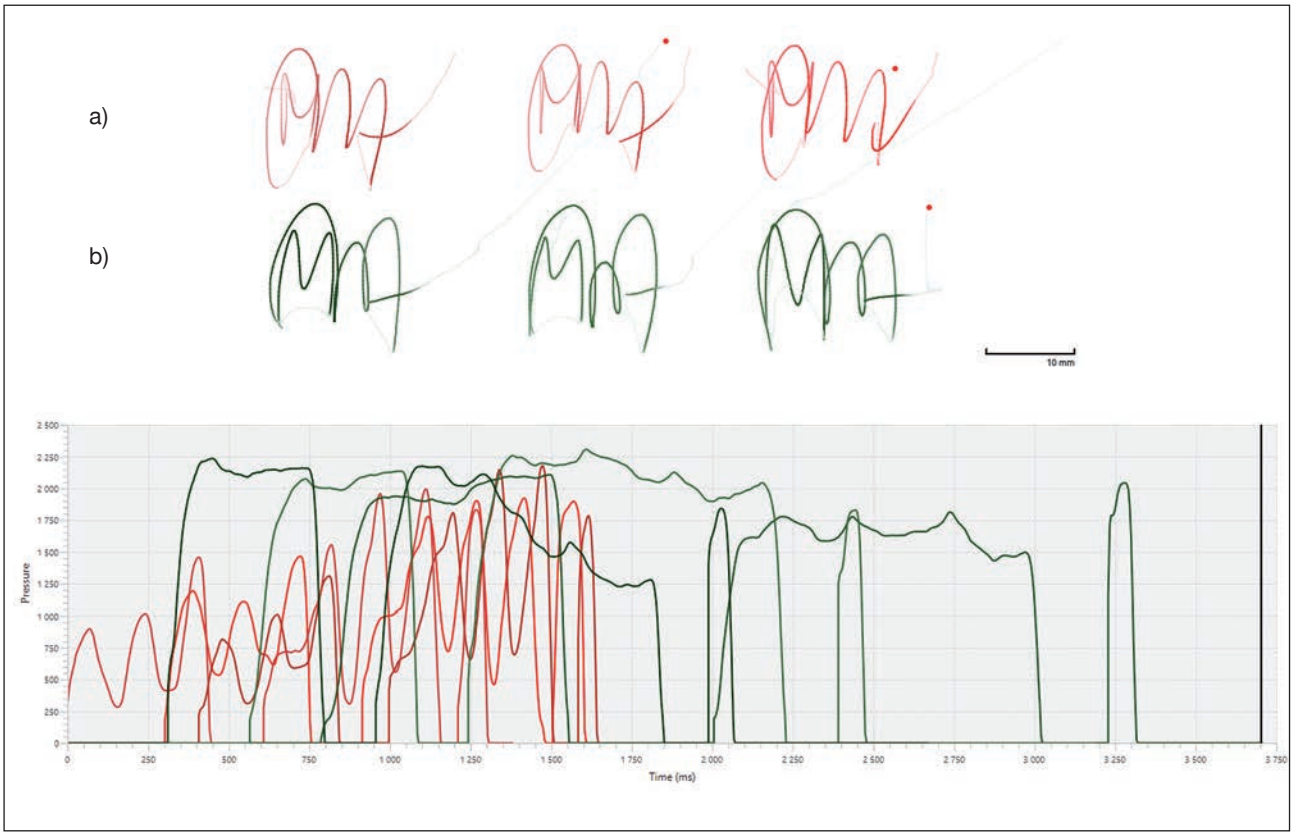

Fig. 8. Pressures in authentic signatures (a) and imitated signatures (b).

Fig. 9. Authentic signatures.

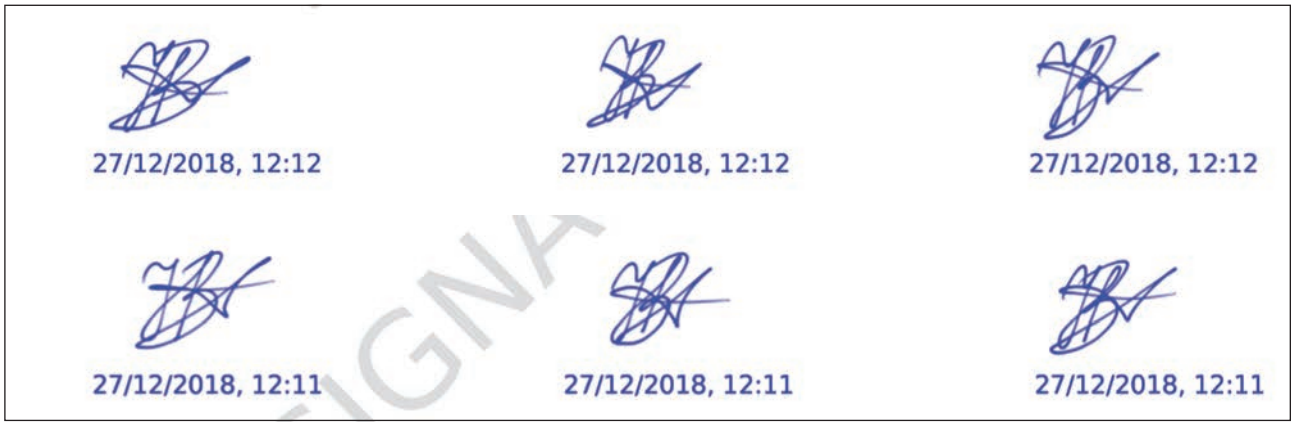

Fig. 10. Imitated signatures.

methods. Figures 9–11 show authentic and imitated signatures and a plot representing the mean pressures for authentic and imitated signatures. In the analysed case, the imitated signatures are characterised by a significantly lower pressure than in the authentic signatures.

Another registered parameter of the biometric signature involves adjustments[6], i.e. all movements taking place above the tablet surface. Their analysis showed that each person submitting the biometric signature performs repetitive and specific movements over the tablet screen. Of course, this also applies to traditional writing on paper but only the biometric signature allows them to be recorded and illustrated. Adjustments in the biometric signature do not constitute the main graphic line of the signature and are not visible on the signed document. Only during the analysis of the signature in an Excel sheet or a computer application intended for that purpose is it possible to extract and evaluate them. A biometric signature enriched with lines drawn over the tablet creates a one-pulse graphic composition that can be the subject of an expert's examination. The advantage of registering this parameter is the unawareness of the person signing it about the possibility of its recording. The imitator focuses on mirroring the image of the signature as much as possible, rather than controlling the movements of the stylus over the tablet. In the case of forged signatures, the adjustment has an irregular and unnatural shape, often with a characteristic tremor.

Figures 12–13 show examples of authentic and imitated signatures with marked adjustments.

Concluding remarks

The results of the conducted research as well as the in-depth analysis and interpretation of the features constituting the examination value of biometric signatures allowed to classify them as object of handwriting identification. The CFLP has issued the first forensic opinions in which biometric signatures were the subject of analyses. Importantly, the opinions led to formulating categorical final conclusions. However, conducting the examinations was possible thanks to

[6] In the traditional model of handwriting analysis, the term 'adjustment' was defined as a graphic element constituting an extension on the basis of the previous hand movement in the air before the beginning of the main writing activity or preparation to the movement of the hand in the air above the background (Koziczak, Owoc, 2007).

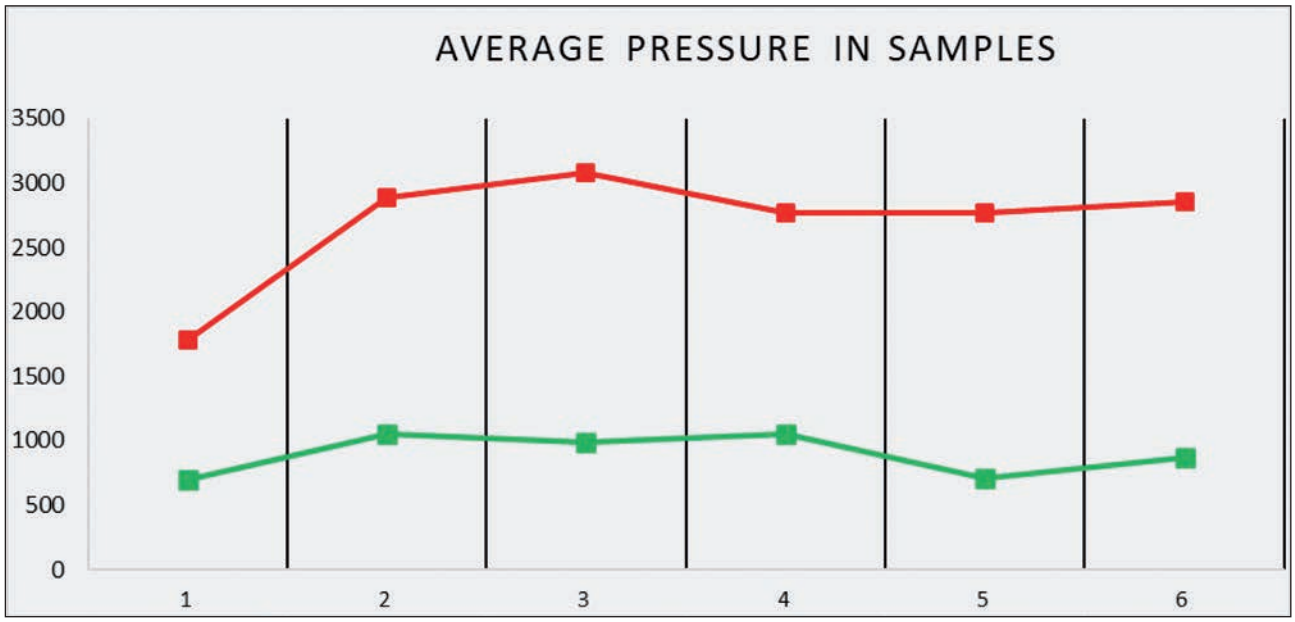

Fig. 11. Pressure values for the authentic signature (red colour) and the imitated one (green colour).

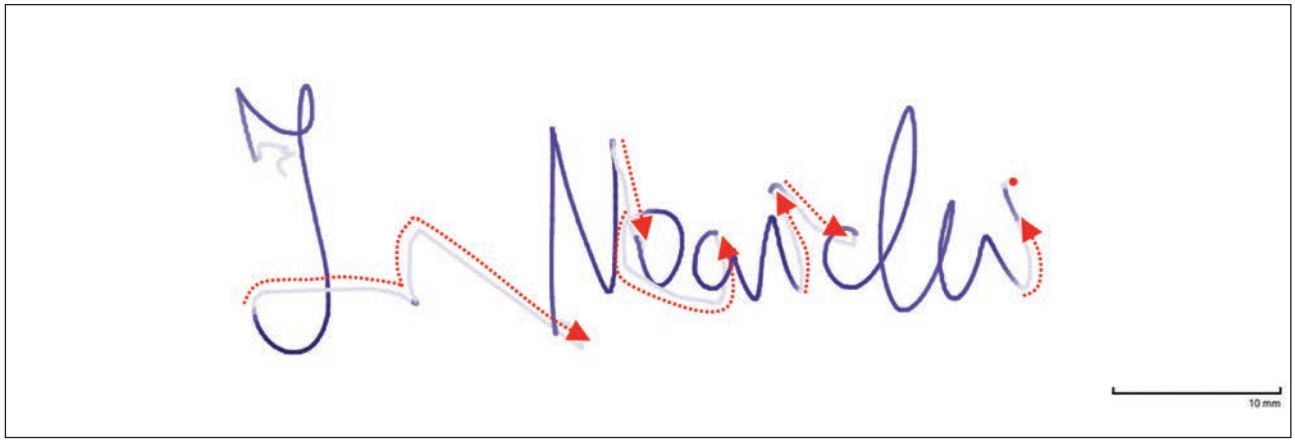

Fig. 12. Authentic signature with marked adjustments.

the close cooperation of the authorities requesting the expertise with CFLP experts in the field of classic document examination. The tasks of the requesting parties included the appropriate recovery of the evidence and collecting the comparative material made on paper background. CFLP experts collected biometric comparative material on the laboratory premises. What is particularly important, the biometric material in each case was submitted on a device and in the computer application analogous to the evidential material. The issues referring to these opinions due to their scientific value will be presented in subsequent publications on biometric signatures. That results from their complexity already at the stage of recovering the evidential material and collecting the comparative material.

Summary

Potential of biometric signatures examination allows minimising the subjective assessment of the characteristics made by the expert in handwriting identification. As the research carried out at the CFLP has shown, this type of signature may be a fully-fledged subject of handwriting examination with the possibility of formulating categorical conclusions based on the analyses. It seems that the popularization of devices and applications recording this form of electronic signature shall determine the direction of development in classic document examination.

Fig. 13. Imitated signatures with marked adjustments.

Source of Figures: Authors

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