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GRAFOTYP V.3.0, OR CHANGING THE ROLE OF THE EXPERT

Summary
The article presents the evolution of the GRAFOTYP program, which is a part of a package of computer programs called "GLOBALGRAF – I", supporting and partially objectifying handwriting identification studies to its GRAFOTYP-3.0 version. The GRAFOTYP program was a development and complement of graphometric methods previously used in handwriting research. In the previous versions of the programme, an important role was played by the expert conducting the research. It was the latter, despite the imposed research rules, who ultimately determined the outline points on the samples analyzed in the program, which the program processed into parameters referred to as the aspect ratio and graphotype. In the new version, the subjectivity of the examiner in determining the contour points in the samples has been eliminated, which allows for uniform results regardless of the user. A key improvement is the introduction of automatic detection of graphic line contours, requiring image binarization. The program has an application in its menu - a graphic editor that allows you to "clean" samples from the background that makes it difficult for the "computer" to conduct analysis without the need to use external analogous tools. Despite the advanced automation of the program, the final interpretation of the test result is still based on the knowledge and experience of the expert who prepares the samples. It seems that the use of the GRAFOTYP 3.0 program may be a significant step towards further objectivization, which will become an important tool in the analysis of scholarly writings.

Keywords: Handwriting identification tests, computer-aided handwriting expertise, GRAFOTYP, GLOBALGRAF, KINEGRAF, RAYGRAF, SCANGRAF, handwriting research

Introduction

The well-known GRAFOTYP[1] program, which has been a component of the GLOBALGRAF[2] package for many years, is a computer graphometric application that allows comparing the compatibility of two records. As a reminder, the principle of this program is to "outline" the contour (which is an irregular polygon) of the record under study and calculate the area " **F"** of this polygon and its perimeter **"P".** The quotient **F/P²** is called the form factor **"Wk".** Then two diagonals of this polygon **"W1"** and **"W2"**are determined, connecting the most characteristic (according to the expert) points of the record. The quotient of these diagonals (the value of the smaller to the larger, that is, **W1/W2** or **W2/W1**) is called the size ratio **"Pw."** Finally, the product of the form factor **"Wk"** and the size ratio **"Pw"** gives the characteristic parameter for a given record called the Graphotype **"G".** Thus, Graphotype is:

$$G = 100 * Wk * Pw$$

The multiplier of 100 was introduced to avoid fractional values (below unity) of the Graphotype that are inconvenient for interpretation and comparison. Calculation of Graphotypes for the two writing samples tested simultaneously, A and B, provides an opportunity to compare and determine their percentage agreement. The application also allows statistical verification of the results obtained[3].

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1 GRAPHOTYP. Scientific work financed by the Ministry of Science and Higher Education with funds for science in 2009-2011 as development project No. OR 00003807 - program guide; authors: A. Luszczuk, K. Luszczuk, scientific consultation T. Tomaszewski, M. Goc, M. Broniarz (electronic version). More extensively on this topic, among others: T. Tomaszewski, M. Goc, A. Łuszczuk, K. Łuszczuk, *Computer-based graphometry - new quality in forensic analysis of handwriting*, in: *Criminalistics and Forensic Examination: Science, Studies, Practice,*part III, Lietuvos tesimo ekspertizės centras, Vilnius 2011, pp. 78-81; M. Goc, A. Łuszczuk, K. Łuszczuk, T. Tomaszewski, *Wykorzystanie grafometrii komputerowej w badaniach identyfikacyjnych pisma ręcznego i podpisów – komunikat z realizacji projektu rozwojowego*, in Z. Kegel, R. Cieśla (eds.), *Znaczenie aktualnych metod badań dokumentów w dowodzeniu sądowym. Materiały XIV Wrocławskiego Sympozjum Badań Pisma*, Katedra Kryminalistyki, Department of Forensic Science, Faculty of Law, Economics and Administration, Wrocław 2010; pp. 94-96; M. Goc, B. Goc-Ryszawa, A. Łuszczuk, K. Łuszczuk, *Grafotyp – program komputerowy wspomagający ekspertyzę pismoznawczą*, „Człowiek i Dokumenty" 2013, no. 30, pp. 65-70; M. Goc, *Współczesny model ekspertyzy pismoznawczej. Wykorzystanie nowych metod i technik badawczych*, Volumina.pl, Warsaw-Szczecin 2015, pp. 246-256; M. Lesniak, *Wartość dowodowa opinii pismoznawczej*, B.S. Training, Pinczow 2012, p. 82.

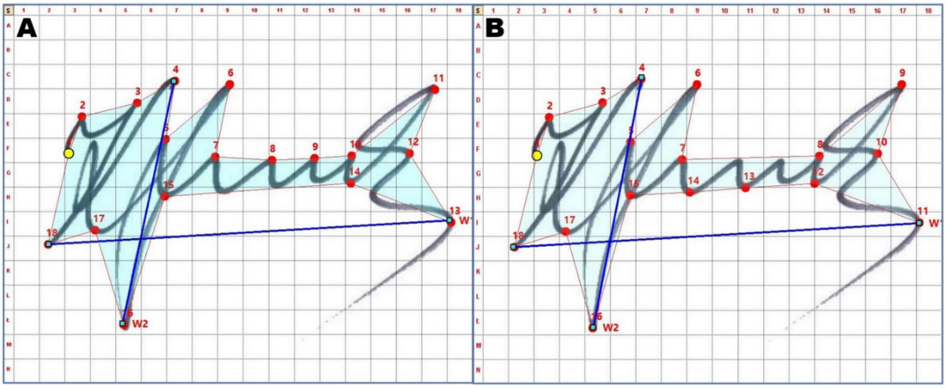
2 GLOBALGRAF was developed in 2009-2011 as part of the project titled. *Development of program methodology and construction of a station for identification studies of writing and signatures using computer graphometry*, funded by the Ministry of Science and Higher Education. The project was a joint scientific and research endeavor of the Department of Forensic Science at the University of Warsaw and the Research and Training Center of the Polish Forensic Association (now the Institute of Forensic Science PTK). The package includes four programs: GRAPHOTYP, KINEGRAPH, RAYGRAPH and SCANGRAPH.

3 In the original version 1.0, the quantile test was used for statistical verification purposes, while in version 2.0 the quantile test was replaced by Spearman's rank correlation. The version 3.0 discussed in this article does not require statistical verification. See also C. Domański, K. Pru-

Subjectivity in GRAFOTYP

Although all the current programs used to support scribal research reduce the subjectivity of research, they do not eliminate it[4]. This shortcoming does not bypass GRAFOTYP either. This is because both the vertices of the aforementioned polygon and its diagonals are determined by the expert (by clicking on selected signature points on the computer screen) based on his knowledge and experience. However, there is no guarantee that any expert examining a particular writing (signature) sample will do so identically. Thus, there is a possibility that a situation may arise in which different experts (e.g., living in different localities, working in different institutions), having the same research material, will give opposite opinions. Verification opinions based on the same research materials, on the other hand, should be consistent. To this end, discretion and subjectivity in taking certain actions must be reduced to a minimum (or preferably - eliminated) from the verification process. Below, Fig. 1 shows an excerpt from the interface of GRAFOTYP v.2.0, containing two identical signatures and their outline polygons, with the location of some sides of the polygons swapped intentionally (the numbers of sides in both polygons are identical).

Fig. 1. Very high similarity of sample outline polygons obtained with GRAFOTYP v.2.0 software



Source: own study.

ska, *Nieklasyczne metody statystyczne*, Polskie Wydawnictwo Ekonomiczne, Warsaw 2000, pp. 204-206 and 212-213.

4 On subjectivity in forensic research, see, among others, J. Moszczynski, *Subiektywizm w badaniach kryminalistycznych. Przyczyny i zakres stosowania subiektywnych ocen w wybranych metodach identyfikacji człowieka*, Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn 2011; A. Koziczak, *Metody pomiarowe w badaniach pismoznawczych*, Wydawnictwo Instytutu Ekspertyz Sądowych, Cracow 1997, pp. 125-132; M. Lesniak, op. cit. pp. 15, 52.

It is worth comparing the location of points numbered 7, 8, 9, 10 in sample A with points 12, 13, 14, 15 in sample B. The former are located above the middle member of the signature, while the latter are located below. Since the geometric shape of the depicted polygons is almost identical, and the diagonals (the blue segments in Fig. 1) connect identical points, the areas of the outlines, the perimeters of the outlines, the shape coefficients Wk, the proportions Pw, as well as the Graphotypes are very similar. Fig. 2 shows these quantities.

Fig. 2. Graphometric parameters after examination of the samples in Fig. 1

Powierzchnia obrysu A	F=121269	Powierzchnia obrysu B	F=121717
Obwód obrysu A	P=2899	Obwód obrysu B	P=2964
Współczynnik kształtu WkA	**1,44**	**Współczynnik kształtu WkB**	**1,39**
Proporcja wielkości PwA	0,62	Proporcja wielkości PwB	0,63
Grafotyp A	**0,89**	**Grafotyp B**	**0,88**

Source: own study.

Such a high numerical similarity in the values of these parameters should, in principle, prejudge the executive compatibility of the samples tested, since each of them contains the same signature. However, this is not the case. Fig. 3 shows the final message, which, despite the very high concordance of the aspect ratios (96.53%) and the concordance of the Graphotypes (98.88%), reports that the location of the subsequent sides of the contours is different. This is determined by a very low (R = 0.294) Spearman rank correlation coefficient, insignificant at N = 18 (number of sides) and α = 0.05, which is a signal of inconsistency in the location of the sides of the "outline" of the samples (as mentioned earlier, drawing the reader's attention to the intended differences in the location of points numbered 7, 8, 9, 10 in sample A and points 12, 13, 14, 15 in sample B).

Fig. 3. Verification message after testing the samples in Fig. 1

Wynik weryfikacji zgodności badanych próbek	x
Zgodność współczynników kształtu	96,53 %
Zgodność grafotypów	98,88 %
Korelacja między długościami boków obrysów	R=0,294 nieistotna (N=18 α=0.05)
Pokaż szczegóły korelacji	Pokaż szczegóły weryfikacji

Source: own study.

More specifically, this means that in identical samples, some contour sections were determined at different (differing) locations, which can result in conforming samples being considered nonconforming, and vice versa. In such a situation, it is not possible to give a categorical opinion on the compatibility of the tested samples. The inconsistency in the location of sections in specific research situations described above can arise for a number of reasons. Sometimes it can be simple carelessness on the part of the expert, sometimes inattention, sometimes indisposition, sometimes failure to read the instruction manual, and sometimes simple ignorance. Whatever the reason for such a significant variation in the location of the "contour" points of the samples, such a situation should not arise. Some "justification" may be the fact that there are no precise, unambiguous guidelines indicating where points should be located on the perimeter of the polygon "outlining" the graphic lines of the samples. There is only a suggestion to "outline" the samples, starting from the starting point of drawing the graphic line. The decision on the location of the subsequent points of the polygon "outline" was left to the experts, and here there is quite a lot of discretion and subjectivity. Therefore, developers are making efforts to ensure that successive versions of the software raise the level of objectivity of the research process, increasing the categorical nature of the opinions given. However, it must be made clear that to date there is not, and most likely will not be for a long time, an application in which the process of verifying the compliance of records is completely independent of the knowledge and experience of the expert using it. The ideal application, eagerly anticipated in scribal research (but also wherever signature verification is needed), would be one in which the expert's role would be limited to preparing samples of evidence and comparison materials, entering them into the application, running it, and waiting for the verdict (conformance or non-conformance) to be given by an appropriately programmed machine. The authors of this article have made such an attempt, and the result is another version of GRAFOTYP. This is version 3.0. In this version, the computer relieves the program user of the task of pointing to the vertices of the "outline" of the graphic line on the screen, as well as determining the diagonals. Thus, any expert examining a particular set of samples should get an identical result.

Principles and conditions of automatic (without the participation of an expert) detection of the contour of the graphic line and determination of its extreme (gabar) points

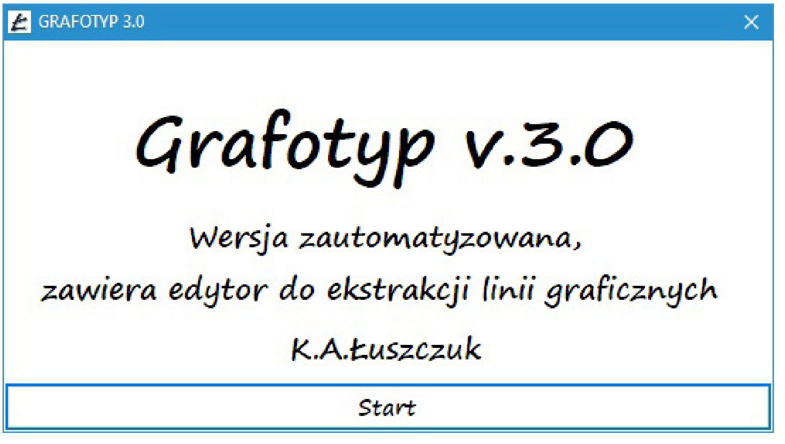
The prerequisite for automatic recognition of the graphic line is its black color on a uniform white background, without any contamination. Obtaining such a sample is possible through the process of image binarization, which is the transformation of bitmaps of images into binary form - containing only black and white pixels, without any intermediate shades of gray. Only then is the computer able to "detect" the graphics line. The algorithm is very simple. When examining the color of each pixel of the sample's bitmap (the sample is a raster image saved in common "jpg", "bmp" or "tif" formats), the white pixels are ignored as belonging to the background, and the black pixels identify the graphic line under examination. In such a prepared sample, finding the coordinates of the extreme (gabar) points of the graphic line is also very easy. Searching the sample bitmap from the left, the first black pixel encountered is labeled as the "extreme left" point, the first black encountered from the right is "extreme right." Similarly, the "extreme top" and "extreme bottom" points are found. Thus, having the graphic line identified by its dimension points, the computer can automatically, without user intervention, determine the necessary parameters of the record under examination. However, samples of records occurring realistically in daily expert practice generally do not meet the condition described above. Most often they have a graphic line background "contaminated" with superfluous elements (rubrics, stamp impressions, various notations, additions, and sometimes simple blots or other stains). It is only by editing such samples, extracting the graphic line to obtain a white background, that they can be studied automatically. Background editing can be done in any graphics editor (e.g. Photoshop, GIMP, Paint, CorelDRAW, Editor or other). Since not every user has access to graphics editors, GRAFOTYP v.3.0 is equipped with its own editor (which we write about later in the article), with the help of which, without "leaving" the program, samples can be adjusted during the test to meet the requirements of automatic detection of graphic lines. It is worth noting at this point that samples of records created on touch screens (Tab.ts) by their nature have a white background, and for their study the editing procedures described above are not needed.

The testing process and compliance verification message will be generated automatically (without the expert's involvement).

Description of GRAFOTYP v.3.0 program

The program's startup window is shown below in Fig. 4.

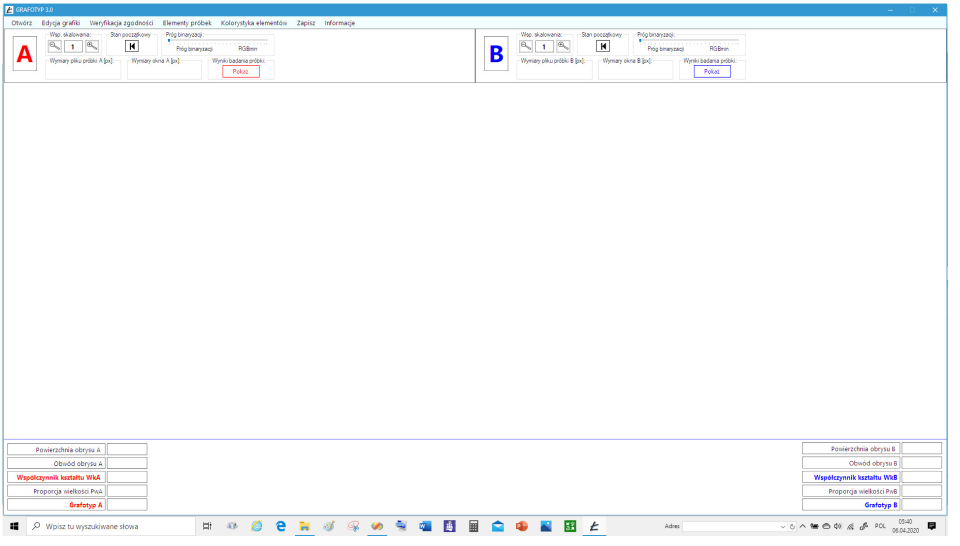
Fig. 4. GRAFOTYP v.3.0 startup window



Source: own study.

Pressing the "Start" button starts the program, displaying its main window.

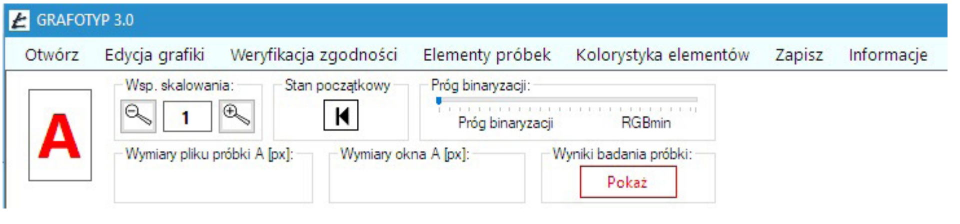
Fig. 5. Main window of the program



Source: own study.

The highly reduced interface, shown in Fig. 5, contains two symmetrical parts, one for sample A and the other for sample B. Because of the downsizing, the interface is poorly legible, but in Fig. 5 the intention was only to show its overall view in full. Below in Fig. 6 are shown, already in readable size, the program menu and toolkit for sample A (identical ones exist for sample B).

Fig. 6. Program menu and toolkit for examining sample A

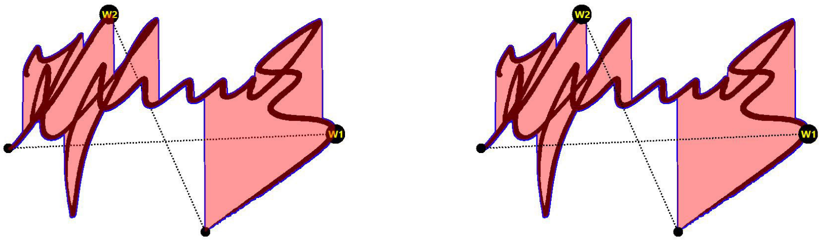


Source: own study.

The expert has only two actions to perform (in addition to opening the samples) (for each sample). First, using the slider in the “Binarization

Threshold” box, he should set its value[5]. The second action is to click the “Show” button in the “Sample results” box, a graphic image of which is shown in Fig. 7.

Fig. 7. Graphical result of the study of samples A and B



Source: own study.

It is worth noting that these are the same two signatures whose “outlines,” determined manually, were presented at the beginning of the article in Fig. 1. The “outline” polygons with a finite, non-minor number of vertices have been replaced by a Fig. that accurately outlines all (not just the expert’s chosen) pixels of the graphic line. The segments connecting the extreme points for calculating the size ratio were also generated by a computer. Everything was done without the human hand with the elimination of arbitrariness in the location of vertex points.

Clearly, in this particular case, since the compatibility of identical signatures was studied, the numerical results of the study should clearly and categorically confirm their compatibility (100%), as shown in Fig. 8 and Fig. 9.

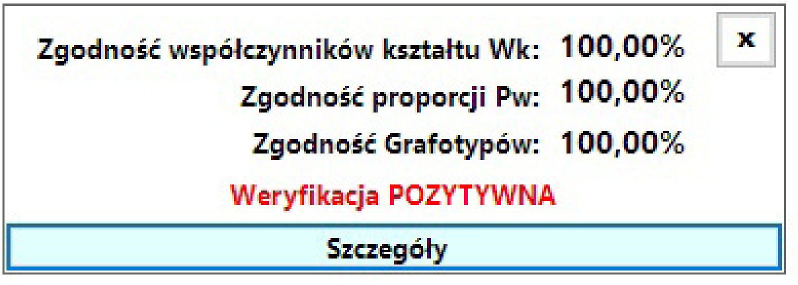
[5] The default binarization threshold is 255 -RGBmin. Moving the “Binarization Threshold” slider to the left or right (this can be carried out repeatedly), the user should set the threshold value according to the needs of the analysis to be carried out, remembering that the analysis should be a black graphic line on a white background. In the binarization process, all pixels of an image with an RGB higher than the binarization threshold (i.e., brighter pixels) are given the color white, while the rest are given the color black. Failure to meet this condition results in completely erroneous test results.

Fig. 8. Numerical results of the survey conducted

Powierzchnia obrysu A	117172	Powierzchnia obrysu B	117172
Obwód obrysu A	2892	Obwód obrysu B	2892
Współczynnik kształtu WkA	1,4	Współczynnik kształtu WkB	1,4
Proporcja wielkości PwA	0,73	Proporcja wielkości PwB	0,73
Grafotyp A	1,02	Grafotyp B	1,02

Source: own study.

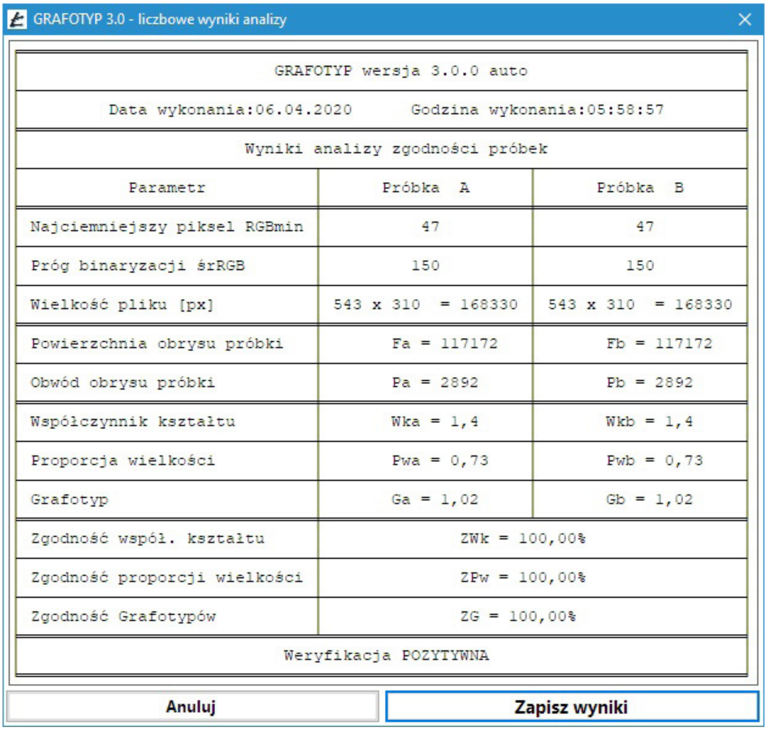
Fig. 9. Verification of compliance



Source: own study.

It is worth noting that there is no rank correlation in this version of the program. It is simply superfluous, because the outline is not a polygon, in which the succession of side lengths is studied (cf. Fig. 3), but an irregular Fig. that does not have the characteristics of a polygon. Pressing the "Details" button displays a window with the complete numerical results of the analysis performed.

Fig. 10. Detailed, numerical results of the analysis with the possibility of saving to a text file

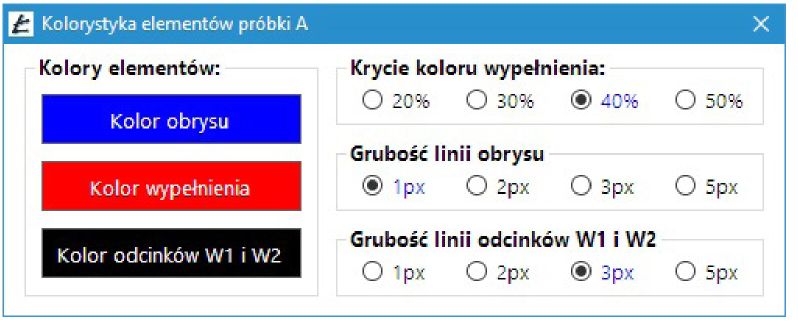


GRAFOTYP wersja 3.0.0 auto		
Data wykonania:06.04.2020	Godzina wykonania:05:58:57	
Wyniki analizy zgodności próbek		
Parametr	Próbka A	Próbka B
Najciemniejszy piksel RGBmin	47	47
Próg binaryzacji śrRGB	150	150
Wielkość pliku [px]	543 x 310 = 168330	543 x 310 = 168330
Powierzchnia obrysu próbki	Fa = 117172	Fb = 117172
Obwód obrysu próbki	Pa = 2892	Pb = 2892
Współczynnik kształtu	Wka = 1,4	Wkb = 1,4
Proporcja wielkości	Pwa = 0,73	Pwb = 0,73
Grafotyp	Ga = 1,02	Gb = 1,02
Zgodność współ. kształtu	ZWk = 100,00%	
Zgodność proporcji wielkości	ZPw = 100,00%	
Zgodność Grafotypów	ZG = 100,00%	
Weryfikacja POZYTYWNA		

Source: own study.

It is also worth noting two menu items of the program, namely “Element colors” and “Sample elements”. Selecting the first one generates the window shown in Fig. 11, giving the option to change the color of the outline line, the fill color, the color of the W1 and W2 sections, and the thickness of the line.

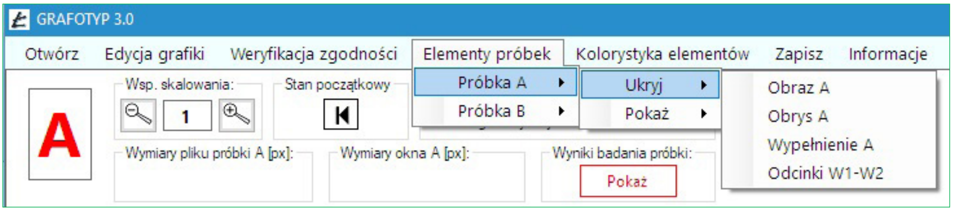
Fig. 11. Possibilities to change the color and geometry of the graphic elements of the analysis



Source: own study.

Selecting the "Sample Elements" option (see Fig. 12) gives the user options for hiding (showing) graphic elements after analysis.

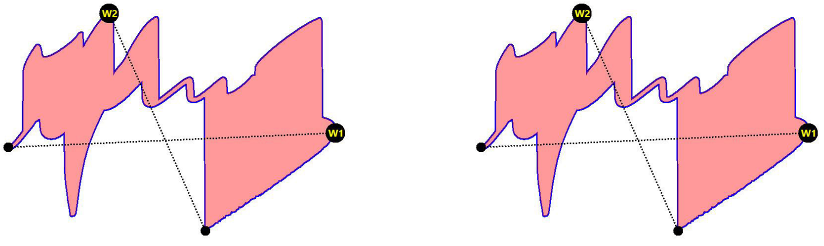
Fig. 12. Options for hiding/showing graphical elements of the analysis



Source: own study.

This option is particularly useful in visually evaluating the results of a study, as it allows the user to view each graphic element separately, which improves readability and facilitates their comparison. For example, Fig. 13 shows the filled-in in color the outlines of the test specimens and the W1 and W2 sections, hiding the graphic lines.

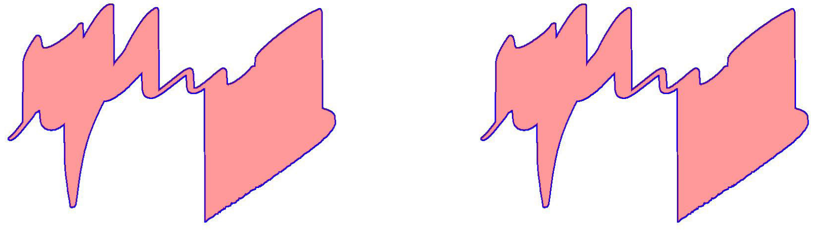
Fig. 13. Outlines of the signatures examined (graphic lines have been hidden)



Source: own study.

On the other hand, in Fig. 14, only the color-filled outlines of the outlines of the graphic lines of the test samples are left.

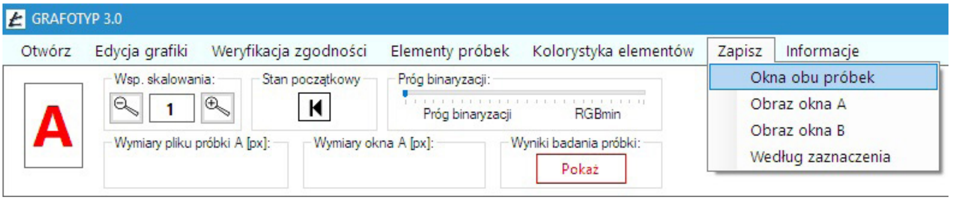
Fig. 14. Outlines of the studied signatures (graphic lines and sections W1 and W2 have been hidden)



Source: own study.

Below in Fig. 15 are the options for saving the graphical elements of the analysis in “jpg” format in any folder designated by the user.

Fig. 15. Options for recording graphic elements of the analysis

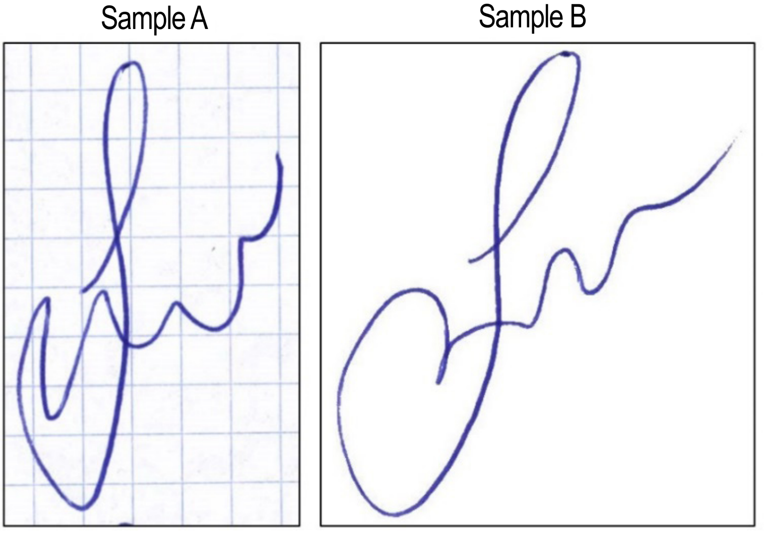


Source: own study.

Example analysis in GRAFOTYP v.3.0 program

Above, we discussed the operation of the program, describing the procedure for comparing two identical signatures, which must have resulted in a 100% match. This comparison is DEMO in nature and is in no way an example of a true analysis. Presented below in Fig. 16 are two paraphrases whose correspondence was verified in GRAFOTYP v.3.0, this time in an authentic analysis.

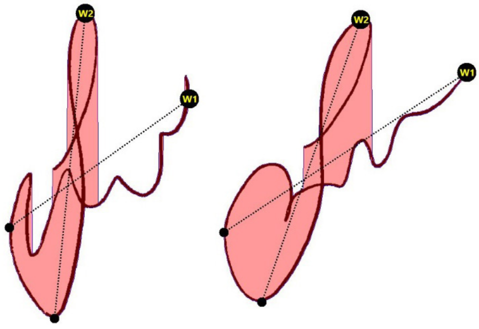
Fig. 16. Examples of parfaits subjected to conformity analysis



Source: own study.

After the user set the binarization threshold, the result was obtained, the graphic of which is shown in Fig. 17.

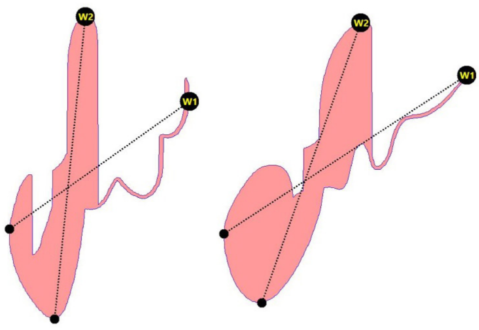
Fig. 17. Examples of parfaits subjected to conformity analysis



Source: own study.

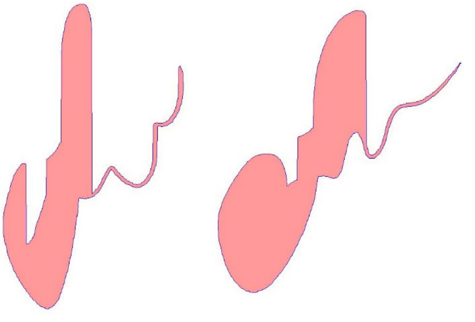
It is worth noting that in the “A” sample, without any additional treatment, the checkered background “disappeared”. More precisely, the background did not “disappear,” but as a result of binarization, the color of the pixels forming the “grid” (which has an RGB higher than the binarization threshold) was replaced by white, as mentioned earlier. Fig.s 18, 19 and 20 show the possibility of separately comparing the graphics of each parameter.

Fig. 18. Result of sample comparison (with hidden graphic lines)



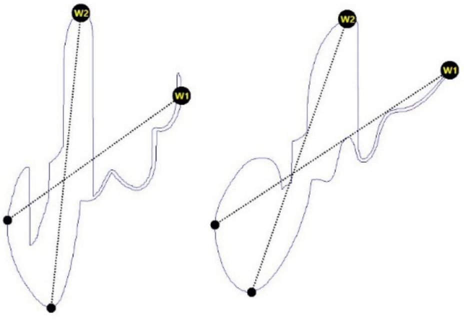
Source: own study.

Fig. 19. Result of sample contour comparison (other hidden parameters)



Source: own study.

Fig. 20. The result of comparing sections W1 and W2



Source: own study.

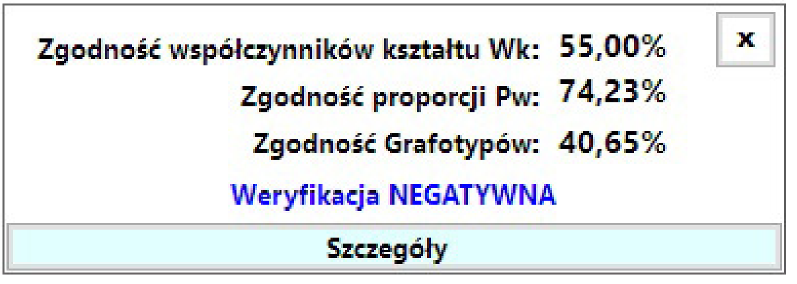
Fig. 21 shows the numerical magnitudes of the compliance analysis parameters, while Fig. 22 shows the final message summarizing the compliance verification.

Fig. 21. Numerical magnitudes of analysis parameters

Powierzchnia obrysu A	57792	Powierzchnia obrysu B	74961
Obwód obrysu A	2556	Obwód obrysu B	2165
Współczynnik kształtu WkA	**0,88**	**Współczynnik kształtu WkB**	**1,6**
Proporcja wielkości PwA	0,72	Proporcja wielkości PwB	0,97
Grafotyp A	**0,63**	**Grafotyp B**	**1,55**

Source: own study.

Fig. 22. Final message on verification results

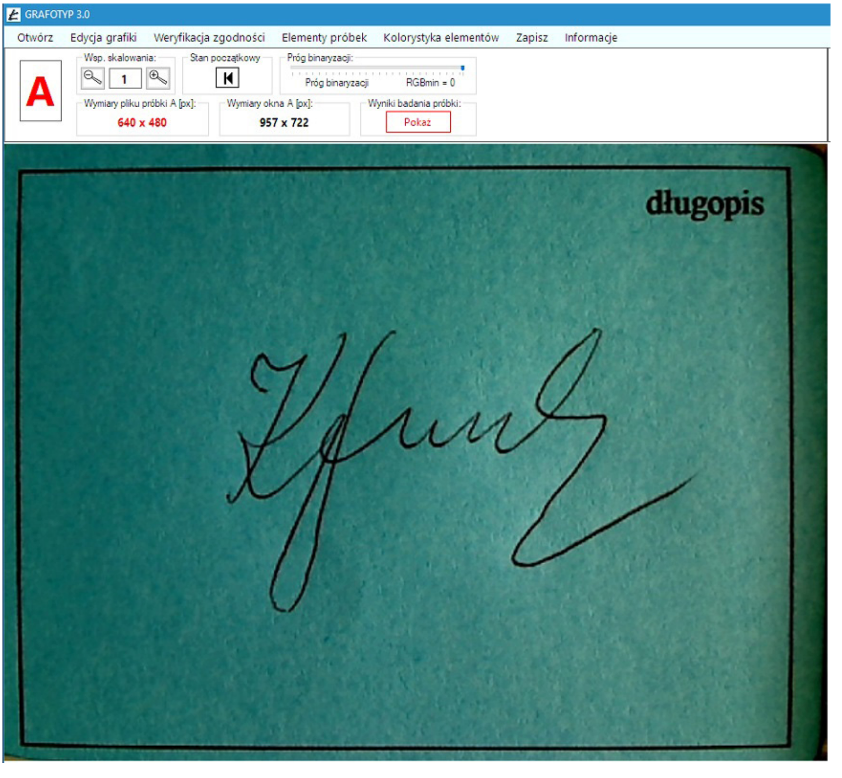


Source: own study.

Sample editing capabilities in GRAFOTYP v.3.0 software

In the parish analysis example described above, in one parish (specifically, parish A), the binarization procedure removed the background, allowing the sample to be automatically tested. This was possible due to the fact that the color of the grids constituting the background is much brighter than the color of the parfait graphic line (the RGB of the color of the grid was higher than the RGB of the line color, which made color filtering possible). This is not always (or rather, often) the case, as often the binarization procedure will not produce a white background. In extreme cases (when the RGB of the elements to be removed is close to the RGB of the color of the graphic line), an attempt to perform binarization will end up removing, along with the background, the graphic line as well, making analysis completely impossible. In such a situation, the only solution is to use some external graphics editor before starting the analysis, and only after obtaining a white background in the sample to direct it for analysis. This was mentioned earlier. However, taking into account the fact that not every scribal expert has software that gives the ability to edit graphics, GRAFOTYP version 3.0 was equipped with its own editor, which will allow to make "extraction" of a graphic line and give it a white background. It is up to the expert to decide whether to use an "external" editor or a resident editor. Below in Fig. 23 is a sample that is not suiTab. for automatic analysis without background editing. However, it is possible to perform editing in the editor[6] implemented into GRAFOTYP v.3.0.

Fig. 23. Sample requiring graphic line extraction



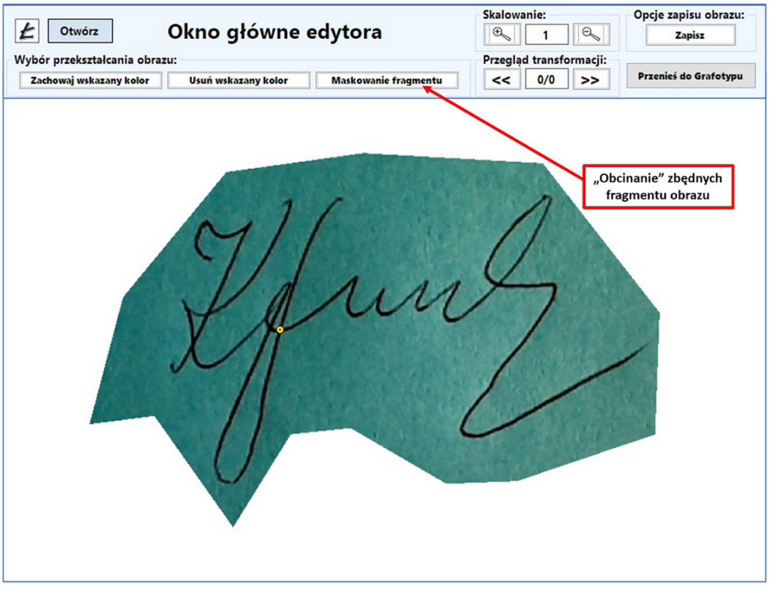
Source: own study.

After selecting "Edit Graphics" from the menu, an editor window opens, into which the sample indicated by the user is "transferred" (see Fig. 24).

[6] A modified Editor program, which we co-authored, was implemented for extracting the graphic line of the samples. The distributor of the Editor program, which can be purchased as a separate application, is the Institute of Forensic Science of the Polish Forensic Association.

From this point on, GRAFOTYP v.3.0 is temporarily invisible (running in the background).

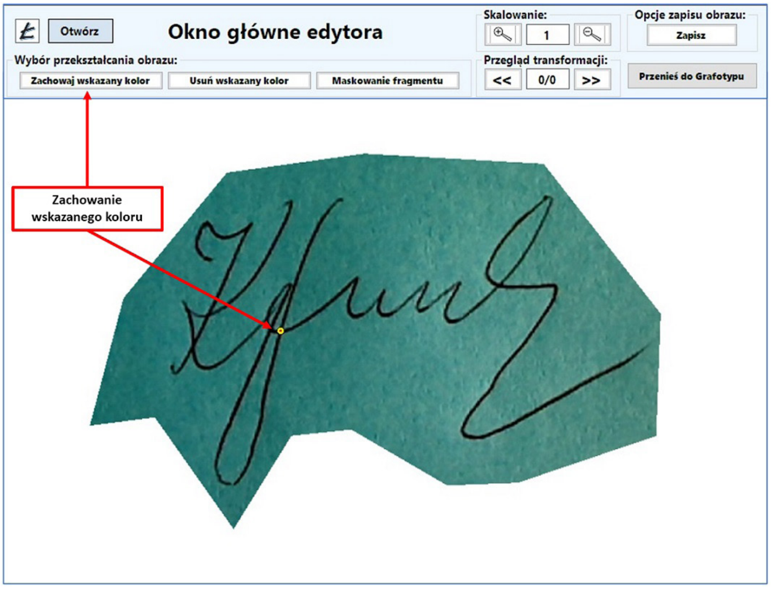
Fig. 24. Samples in the graphics editor (removing unnecessary elements)



Source: own study.

In the main window of the editor, selecting the “Masking a fragment” option, we remove unnecessary elements of the image, “painting” them with white color. Next, we select the “Keep indicated color” option and indicate the point on the graphic line whose color will be kept (Fig. 25).

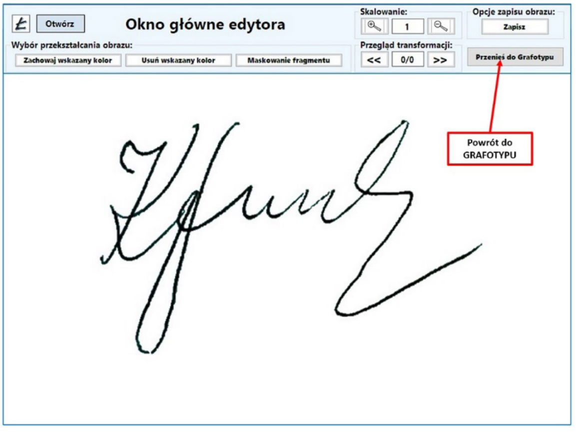
Fig. 25. Samples in the graphics editor (retaining the indicated color)



Source: own study.

As a result of the “Keep indicated color” option, the plane of green color in Fig. 25 is replaced by white, and a clean graphic line remains in the image, as shown in Fig. 26.

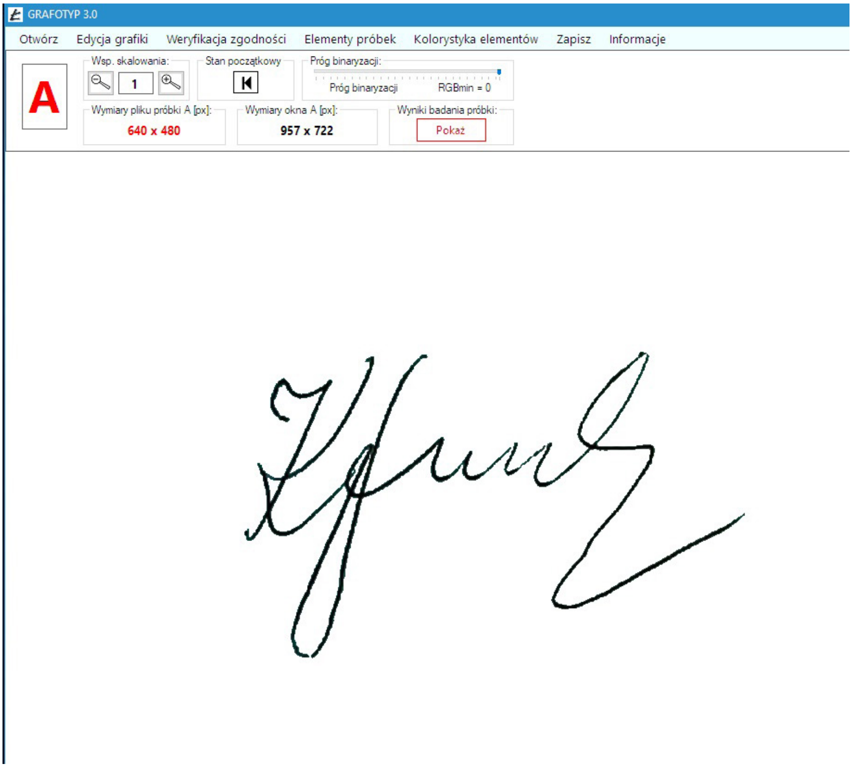
Fig. 26. Samples in the graphics editor (back to analysis in GRAFOTYP)



Source: own study.

If the user decides that the result of the graphical line extraction is satisfactory and does not need to be corrected, the selection of the "Transfer to Graphotype" button closes the editor, and the image of the sample in the new graphical "dress" goes back to GRAFOTYP v.3.0, where the analysis can be carried out (see Fig. 27).

Fig. 27. Sample again in GRAFOTYP ready for analysis after graphic line extraction



Source: own study.

Summary

From the content of the article, it appears that the scribe expert, using GRAFOTYP v.3.0 software, has little influence on the very process of verifying the compliance of the records under examination. The computer takes out all the essential work for him, greatly increasing the objectivity of the comparative analysis. However, this marks a definite change in emphasis in terms of the expert's work. The gravity shifts from analysis per se to the sample preparation process. Proper preparation of them, based on expert knowledge and experience, while objectifying the analysis by the proposed software will certainly raise the categoricality of the judgments made.

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Other

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