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ПРОБЛЕМИ КРИМІНАЛІСТИЧНОЇ ІДЕНТИФІКАЦІЇ ПОЧЕРКУ У СУДОВІЙ ЕКСПЕРТИЗІ

Анотація. *Власноручний підпис як характеристика аутентифікації була юридично і суспільно визнана протягом століть і вже багато десятиліть використовується в криміналістичній області для ідентифікації автора. Підходи до біометричної аутентифікації користувача, розроблені в останні роки, також частково засновані на характеристиках почерку, таких як автоматична перевірка підпису. У цій статті систематично виявляються особливості почерку, опубліковані в галузі криміналістики, і аналізується, які з цих властивостей можуть бути адаптовані у вигляді біометричних ознак для перевірки користувача. Представлена процедура перевірки користувача, заснована на наборі з 14 характеристик криміналістики, яка інтегрується в процедуру біометричної перевірки. Результати перевірки цих криміналістичних ознак зіставляються в детальних тестах з ознаками не криміналістично обґрунтованих даних, і показано, що значні поліпшення в показниках помилкового виявлення досяжні шляхом включення криміналістики. Протягом сотень років власноручний підпис був юридично і соціально визнаним в якості аутентифікації. Причиною цього є унікальність почерку людини. Хоча фальсифікатор з деякою практикою може візуально імітувати текст або підпис іншої людини, типові сліди, що виникають з (вивченої) поведінки жертви підробки, важко скопіювати. Для перевірки запису використовується сила тиску всіх точок накладення за допомогою пера на початку або всередині слова, написаних букв у висячому положенні. Крім того, те, як письменник несвідомо або навіть свідомо пов'язує слова, літери або частини букв один з одним, є специфічною рисою для цієї людини. У судову експертизу фахівці досліджують ці та інші ознаки, щоб довести або спростувати справжність підписів або документів. В області наукового криміналістичного дослідження писемності існує безліч процедур, пропонує на основі фізичних зразків почерку для визначення письменника*

Ключові слова: ідентифікація, почерк, писемність, криміналістика, підписи

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PROBLEMS OF FORENSIC IDENTIFICATION OF HANDWRITING IN FORENSIC EXAMINATION

Abstract. *The handwritten signature as a characteristic of authentication has been legally and publicly recognised for centuries and has been used in the forensic field for many decades to identify an author. Approaches to biometric user authentication developed in recent years are also based in part on handwriting characteristics, such as automatic signature verification. This article systematically identifies handwriting features published in forensics and analyses which of these properties can be adapted as biometrics to verify the user. A user verification procedure based on a set of 14 forensic characteristics is presented, which is integrated into the biometric verification procedure. The results of the verification of these forensic features are compared in detailed tests with the features of non-forensic data, and it is shown that significant improvements in false detection rates can be achieved by including forensics. For hundreds of years, handwritten signatures have been legally and socially recognised as authentication. The reason for this is the uniqueness of human handwriting. Although a forger with some practice may visually imitate another person's text or signature, the typical traces resulting from the (studied) behaviour of a victim of forgery are difficult to copy. To check the record, the pressure force of all overlay points with a pen at the beginning or inside the word, written letters on the weight are used. In addition, the way a writer unconsciously or even consciously connects words, letters, or parts of letters to each other is a specific trait for that person. In a forensic examination, experts examine these and other features to prove or disprove the authenticity of signatures or documents. In the field of forensic science, there are many procedures offered based on physical handwriting samples to determine a writer*

Keywords: *identification, handwriting, writing, criminology, signatures*

INTRODUCTION

Today, most modern scientists consider forensic identification in three aspects: as a private-scientific forensic theory (a separate method of cognition) – the doctrine of the general laws of establishing the identity of material objects to themselves in different periods of time. Forensic identification includes the doctrine of general principles and methods of identification of material objects as a way

to establish the truth in a criminal, civil, administrative, economic case, or as a way to obtain individual evidence; as a research process that allows establishing the presence or absence of an identity of an object to itself by certain reflections in the external world, that is, to establish a single object associated with a crime. In this case, forensic identification is understood as a system of actions

performed in a certain sequence; as a goal or result is the establishment of the fact of the presence or absence of an identity, which can be evidence in criminal proceedings.

Given the diversity of views of scientists on the nature and significance of forensic identification, its tasks are also interpreted differently. Thus, scientists determined the task of forensic identification to obtain forensic proof of identity [1], considered the task of forensic identification in establishing the fact of identity or obtaining proof of identity, analysed the task of identification in obtaining evidence confirming or denying identity [2], forensic identification in the establishment of a separate material object, it was proposed to consider the tasks of forensic identification as the determination of the identification set of features necessary to deduce the identity and authenticity of physical evidence and the like [3].

Given the differences in the views of scholars on the problem of forensic identification, it is appropriate, in the authors' opinion, the view of the close relationship of the problem of forensic identification as a structural element of the evidentiary process with the problem of criminal justice in general [4]. If to consider forensic identification as a relatively independent complex organised system of cognitive actions in the field of criminal proceedings, it is appropriate to distinguish its general and individual tasks. At the same time, existing research in the field of forensic identification allows considering it as a structural element of a more complex system of cognitive actions – evidence and criminal proceedings in general, where forensic identification is one of the individual tasks, which contributes to the overall goal of proof.

The founder of the scientific doctrine of forensic identification S.M. Potapov [5], noted that the main task and goal of all forensic methods (technical and tactical) is to obtain forensic proof of identity as a result of a study called identification. So, S.M. Potapov limited the tasks of forensic identification to the framework of judicial proceedings, scientist understood its tasks in establishing a specific individual object in its various states and manifestations, not limited to the framework of judicial proceedings, but narrowing the objects of identification – things, faces, animals [6]. Disclosing the tasks of forensic identification as a means of cognition of objective reality, one cannot ignore its tasks as an element of a general scientific epistemological means – a comparative analysis aimed at establishing the presence or absence of identity.

A specific feature of forensic identification is that it is not only a means of knowledge, but also a means of proof, which determines not only the special scope of its implementation, as well as the specifics of its objects, subjects and the like. Regarding this understanding of the nature of forensic identification, the authors agree with the opinion [7], who noted that since general scientific identification is a means of identification-distinction, its purpose is to resolve issues of identity, i.e. to establish its presence or absence. And since forensic identification is also a means of solving problems in the field of judicial proceedings, its purpose follows from the purpose of the activities in which it is carried out. And if the activity in the field of criminal proceedings is one of the forms of

realisation of legal relations by proving, then forensic identification is a means of their realisation (that is, a means of proof), and therefore its purpose should be aimed at the realisation of such legal relations. In this case, the main forensic task is not to obtain judicial proof of identity, but a procedural solution to the issue of identity, which involves either obtaining proof of its existence or obtaining proof of its absence.

The traditional assertion that the modern understanding of forensic identification no longer fully meets scientific as well as practical needs is a well-founded number of factors and scientific positions. This concerns, first of all, the need to clarify and determine the place of identification by mental (ideal) images among other types of forensic identification. Characterising the identification of mental images in the system of forensic identification actions, there is a need to shed light on its concept and essence as a legal phenomenon existing in the legal system. Identification by mental (ideal) images is a scientific concept that is a form of human thinking. The concept provides a basis for understanding and cognition of the essence of a phenomenon or process. It is with the help of the concept in the form of abstract thinking that the essential features of the object of study were generalised.

In the scientific literature, the word “concept” is interpreted as a thought that reflects in a generalised and abstract form objects, phenomena and the relationship between them by fixing the general and special features – the properties of objects and phenomena [8]. That is, the scientific concept should be understood as a certain form of thinking (thought, position, recommendation), which reflects the common essential properties of a phenomenon of objective reality, the general relationship between them as a holistic set of features, and the essence is the content of the phenomenon, external manifestation which is only a certain aspect of its essence, cognition of which is carried out by analysis and synthesis, directed to the depth of the phenomenon, from phenomenon to essence, from the essence of the first order to the essence of the next order, and so on to infinity [9]. In the philosophical sense, essence is a category of dialectics that reflects the patterns that occur in the phenomenon and represent a set of its internal connections [10]. Therefore, such phenomena as “concepts” and “essence” are complementary and interconnected terms in the study of concepts, features and features of identification by imaginary images.

It should be noted that the concept is a phenomenon of objective reality, which is perceived based on its features, and the essence of the latter can be revealed through in-depth research. First of all, it concerns the understanding of the phenomenon that is being studied. After all, identification by mental images can be most fully characterised through the concepts, features and forms of forensic identification, in particular when conducting expert research. The effective operation of pre-trial investigation bodies depends not only on the proper performance of their tasks, within their competence, but also on the quality of application of both the rules of criminal procedure and the provisions of criminology. This applies, in particular, to such a specific method as forensic identification, the essence of which is

the ability to perform narrow identification tasks to establish the identity of a particular object that has a stable external form.

1. MATERIALS AND METHODS

The identification of an object by its mappings occurs in those cases when, along with the predominant coincidences, insignificant differences are also noted. However, clearly defined differences, showing a dissimilarity in the main, are the basis for differentiation (the principle of the opposite phenomenon of identification). If it is impossible to find out the nature of the differences, and then classify them as significant or insignificant, it is necessary to conclude that it is impossible to identify. Criminal procedural evidence is defined as the activity of the relevant bodies and persons carried out in procedural forms and consists in the collection, verification and evaluation of evidence in order to establish the circumstances relevant to the criminal proceedings. The authors studied that forensic identification acts as one of the important tools of the process of proof, based on which it is possible to find out the essence of identification as a way of equating material objects by their mappings.

In criminology, the position on the essence of identification is deeply researched and theoretically explained. A separate theory of forensic identification has been developed, which is of great practical importance in criminal proceedings. Therefore, when establishing the place of identification with mental images among other types of forensic identification, it is appropriate to take as a basis the essential understanding of forensic identification and the classification of identification actions. The essence of forensic identification as a general scientific category is to identify the object (person, thing) by separating it from similar objects to solve the problems of criminal proceedings. Forensic identification is not only a specific method, the purpose of cognition, but also a cognitive process, which is realised through instrumental research, investigative (investigative) actions or operational and investigative measures. In modern forensic science, forensic identification is understood as a method of establishing relative or absolute truth in criminal proceedings. It, in turn, means the establishment of the coincidence of the characteristics of an object or person in a set of certain general and individual features [11].

The purpose of criminal proceedings is to establish the truth (falsity) only of those circumstances of criminal proceedings that have legal significance, and not to establish the truth in criminal proceedings as a whole. At the same time, the goal of forensic identification by imaginary images is somewhat different, because in its essence it consists in finding the truth in the process of criminal proceedings directly during identification, since it is aimed at individual identification, that is, at establishing the complete coincidence of the features of a particular object. Based on the foregoing, determining the place of identification with mental images among other types of forensic identification, it is possible to conclude that these concepts of classification of identification actions have become the basis for distinguishing two main forms

of reflection in the modern science of forensic science, namely: materially fixed and ideal (in separate sources – psychophysiological, mental, imaginary). The ideal form of reflection, in turn, is subjective and consists in fixing a mental image of an object in the memory of a particular person.

2. RESULTS AND DISCUSSION

In the forensic literature, the issue of classification of identification actions has traditionally been covered by the concept of “types and forms of forensic identification”. At the same time, the concepts “types” and “forms” are interpreted as synonyms, which is also incorrect from a methodological point of view. This is due to the fact that, when characterising the forms and types of forensic identification, one should first of all proceed from the fact that when classifying any objects (including identification actions), it is about their ordering by dividing them into groups according to certain criteria. As for the concept of “form”, it comes from the Latin “forma” and is traditionally interpreted as the appearance of a certain object. However, for example, Hegel distinguished both external and internal forms, which from the standpoint of the modern understanding of these problems is not entirely correct, since the concept of “internal form” is more precisely covered by the concept of “structure” of an object. That is why, when classifying forensic actions, which are the basis for determining the place of identification with mental images among other types of forensic identification, the form is one of the grounds for separating them into a separate group (type) [9].

It should be borne in mind that forensic identification, which develops from the practical needs of using the methods of natural and technical sciences in the investigation of crimes, is one of the varieties of general scientific identification and, from an epistemological standpoint, is a special case of pattern recognition [12]. That is why, when determining the value of identification with mental images, one should take into account, on the one hand, general scientific foundations, and on the other, specific (actually forensic) features of the types and forms of forensic identification. This is explained by the fact that identification studies are primarily a means of cognition, and in legal proceedings they also perform the function of a means of proof, which is the basis for identifying their procedural and non-procedural forms. In the theory of forensic science, as the identification of a person by mental images, its identification by signs of appearance is considered. The doctrine of forensic habitology is a set of theoretical provisions on the features of a person’s appearance, methods of identifying, studying and using them in order to solve the problems of criminal proceedings.

Signs of a person’s appearance can be divided into two groups: own signs and accompanying ones. First of all, self-signs are those signs that belong to a person from birth or are naturally acquired in the process of life. This concerns the structure of a body, a face, the organic properties of his appearance, which are integral to him. So, for example, the structure of the skeleton of a face, which grows and changes throughout lifetime, but this process is characteristic of the internal life processes of a human body. For these reasons,

in the theories of criminalistics identification and criminal procedure, a controversial problem has been formed about the existence of the evidentiary value of carrying out the identification of an object on other grounds. Modern scientists studying this issue believe that the identification of the essence of presentation for identification as an investigative (search) action, during which participants in criminal proceedings face for identification objects of the material world previously perceived by them or carriers of objective representations of these objects, causally related to the event of a crime in order to establish identity, group affiliation or distinction. Identification parade is based on the process of comparative analysis of an object displayed in a person's memory and an object presented for research [13].

During identification by mental images in the process of presentation for identification, a person who recognises compares the signs and properties of the proposed objects with the mental (ideal) image preserved in the memory of the person due to the previously perceived object. As a consequence, the person who recognises makes a conclusion about identity, similarity, or difference. Therefore, the psychological content of perception should be considered a feature of identification by mental images during identification. So, distinguish between successive and sympathetic recognition. In the case of a successive identification of an object according to imaginary images, a sequential comparison of the features of the image previously perceived by a subject with a presented object is carried out. Simulative identification of an object by mental images during identification is carried out simultaneously due to the identification of a well-known object. In the forensic literature, the opinion is expressed that the propensity for simulative or successive identification by mental images depends on the individual mental characteristics of a person. The identification performance is influenced by the social experience of the identifier, his volitional activity, the type of memory, the time elapsed from the moment the object was perceived to the moment it was presented for recognition, and other conditions [2]. However, in the indicated context, it should be agreed that the characteristics of these two types of perception are rarely met in their pure form. They usually complement each other, since the most productive perception is based on the positive characteristics of both types. This perception combines elements of synthetic and analytical thinking [14].

Based on the foregoing, it can be concluded that the psychological properties of a subject that recognises must also include the features of identification with mental images. This is due to the fact that the choice of the type of psychological identification (recognisability behind mental images) depends not only on the type of memory of a person who recognises but also on the characteristics of the previous interaction of such a person with an object that is being identified. The authors found confirmation of the above in the materials of investigative (operational) practice, where there was identification of a person by mental images when presented for identification of a living person by functional, dynamic features, such as speech, gait, voice, facial expressions. So, according to the

materials of the investigative practice, in the case of theft in the hostel, the tape recorder was stolen from the victim A., where three other guys lived with him in the room. A neighbour from another room, B. (the witness) heard in the victim's room a conversation between the accused and a stranger, but did not see his face. An investigator carried out an investigative (search) action of presentation for identification by voice [6]. In this case, witness B, of course, could not single out individual functional features of a subject, but he perceived a subject of identification as a whole, that is, there was a simulative identification of a subject in mental images.

The above gives grounds for the conclusion that forensic identification by imaginary images should be understood as a process in which various subjects participate (subjects of proof and subjects of identification); in the form of expression by a procedural identification action, it is carried out in the field of procedural activities in order to obtain judicial evidence of identity by using the cognitive capabilities of a subject of identification, which is a source of information about facts. The purpose of forensic identification is individual identification, that is, establishing the coincidence of the features of a particular object and the search for truth directly during identification. Although in science forensic identification is characterised by various criteria, the most informative of them in characterising identification with mental images are: its belonging to procedural identification actions; the special nature of knowledge that is used in the identification process; the goal and tasks that determine its implementation (for the purpose of individual identification, that is, establishing the complete coincidence of the features of a particular object; in order to search for the truth directly during identification).

With computers and equipment such as tablets, pressure-sensitive displays in personal digital assistants (PDAs) or tablet PCs, there are many possibilities today for capturing and manipulating digital ink. With computer capture from manuscripts, it is possible to register dynamic characteristics already during handwriting recording, which must be evaluated or measured accurately enough in a forensic medical examination. In connection with these new ways of recording both the writing process and the resulting font, the discipline of dynamic biometric handwriting recognition has been traced for about two decades, which can find application, for example, in the field of electronic signatures [1; 6; 11]. Here, from the recorded physical measurements of the recording process, characteristics are determined based, for example, on the speed, pressure, or change in an angle of a pen during recording. There are many biometric methods for verifying a writer today, a full overview can be found [2; 3; 14; 16]. Although the scientific disciplines of writing forensics and handwriting biometrics suggest a close relationship due to their nature, there are several cross-disciplinary approaches to authorship verification.

Thus, studies of biometric-based writer's forensic verification can be found in full font such as letter [3]. However, no approaches to the safety of authorship have been found. This study aims to show the extent to which

the approaches and methods of forensic font research can be transferred to computer biometric user authentication. In addition to the results of quantitative research, such as the adaptation of established research methods from forensic science to biometrics and the study of their suitability in the experiment, the authors also focus on the qualitative aspects. These qualitative considerations made it possible to compare scores from both disciplines that can be useful in non-technical evaluations of biometric systems. The authors' contribution is divided as follows: first, an overview of the objectives of forensic writing and presentation of the important core components of forensic analysis. The authors briefly stop on the formation of features based on online manuscripts, in order to then present and qualitatively discuss the comparison of forensic and biometric characteristics. The authors present the current test results for the selected characteristics presented, and in the conclusion we will summarise the message and give an idea of future work.

Forensic handwriting examination studies the authenticity of handwriting by hand or in the signature of documents. Such documents include, for example, contracts, receipts or anonymous letters. Important features of font of components when examining handwriting in words or numbers with a signature. In doing so, it can be checked whether the three values belong to the same

person, whether the signature belongs to an account owner, or individual data (for example, the amount) has been changed. Obviously, it is not always necessary to check all possible combinations. Thus, in the event of a dispute over a specified amount of money in a handwritten contractual document, it is sufficient to simply examine it for possible manipulation [12; 15]. At the same time, there is no need to check the signatures on this document if the disputing parties do not doubt its authenticity. Also, forensic handwritten examination is engaged in determining the time sequence of the creation of both several documents and several parts of a text of a document. These techniques help to verify the true authorship of a document. For the systematic analysis of manuscripts in forensic science, basic expressions are used. When studying the stroke as the main component of the font, material and technical conditions play an important role. The texture of a line depends not only on a writer but also on the writing instrument, the medium of font, and the writing surface. To assess the texture of a line, in most cases it is necessary to increase the material to detect and evaluate even the smallest features. Examples of this are the difference in movement of a pen while writing, as shown in Figure 1. These are the smallest strokes that occur when a pen is pressed and released and is very specific.

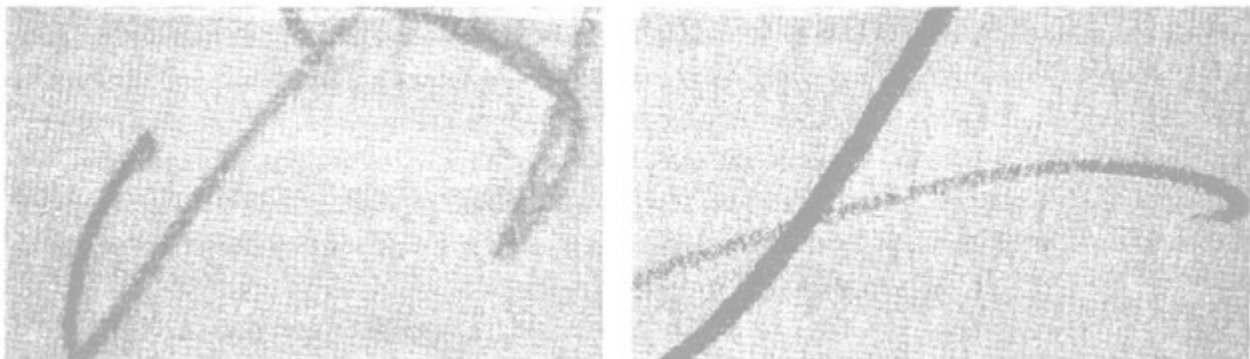


Figure 1. Continuous and intermittent movement of a pen

The print evaluation examines how hard the writing instrument has been pressed against the type medium. Print marks on paper vary by author, writing instrument and writing surface. The exact writing pressure can only be established while writing with special devices. For example, for a ready-made font, the print can be judged by the depth of the grooves for printing on paper. It should be borne in mind that a softer board can also lead to a deeper groove like a complex writing device (e.g. pencil). Other indications when studying pressure are line width, degree of colour. In movement flow, aspects of speed or timing are evaluated, as well as the degree of cohesion or binding of letters.

The motion may flow (walk) continuously during

recording, or it is frequently interrupted and this slows down the recording speed. The tempo characteristics of recording performance can only be measured when provided. Otherwise, they must be evaluated by an expert. This basic graphics component deals with posing the question of how an author handled and applied the school pattern that he learned to write from. Which parts were taken from him, and which were adapted to his personal manner of writing. The elementary written movements of each school template consist of a line (straight), an arc (circular) guiding movement, and the resulting blended shapes, as shown in Figure 2 [16; 17]. Since angular movements occur when moving along the line of change of direction, they are also called angular.

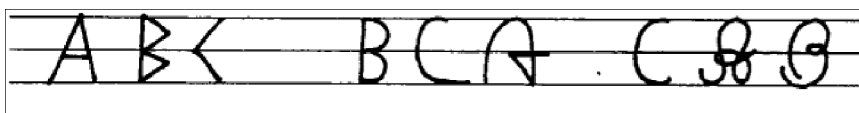


Figure 2. Pure line, blended shape, angular movements

The main component “direction of movement” is summarised as the development of a movement in the four recording directions. These include the ratio of the angles of a character to a baseline, all text to paper, or each letter,

as well as the order in which the constituent parts of a letter or word were written. Figure 3 shows the different movements when writing a letter.

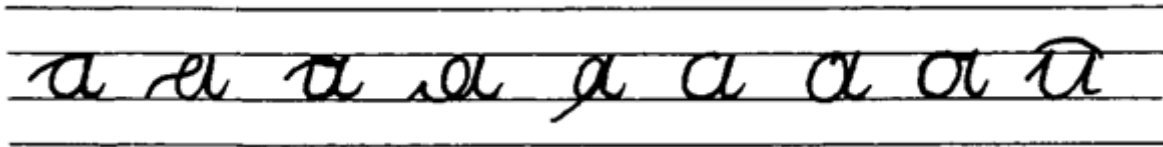


Figure 3. Different sequence of movement with the same basic spelling

The vertical extent determines the size and aspect ratio of the font size. Thus, it may be typical for a person that, regardless of the space available, he always writes his signature in the same size. However, if a signature on a form matches a default size, it could indicate a forgery. Horizontal expansion considers the primary width (letter width) and secondary distance (letter distance). In this case, the ratio of the font width to its size matters. When studying horizontal expansion, one should pay attention, first of all, to stretch marks and pressings inside and between letters. It is important to note whether they are attached to the same characters or the same letters, letter connections, or specific positions, or show the same irregular variation. This basic graphics component describes how the write performance has been blended into the accessible area in terms of horizontal font. Depending on the original media requirements of font and write performance, the writing ability of font can vary greatly.

Greatest writing possibilities offers a blank non-linear sheet without specifying what a person should write. However, if a signature is required, which must be done in a small rectangle in a form, the writer’s expandability is severely limited. In addition, other anomalies should be considered when comparing fonts. Spelling, punctuation, or other personality traits such as abbreviations or dates are important features here. Other examples of anomalies

include fall-back strokes in totals, underscores, or strike-throughs. Next, there is a fundamental overview of the characteristics that can be derived from capturing the dynamics of handwriting during recording and used for biometric user authentication. In addition to functional and structural assessments, there is the possibility of statistical analysis of those quantities on which the authors will focus. These values are determined based on statistical estimates of the signals recorded during writing [18; 19].

Modern digitisation of a tablet makes it possible to record up to five independent signals: $x(t)$: signal of the horizontal position of the pen $y(t)$: the vertical signal of the position of the pen; $p(t)$: pressure gradient signal applied to the pen tip; $\Phi(t)$: angle of the pen height above the tray; $\Theta(t)$: side angle of the pen above the tray. Based on these physical measurements, various statistics can be mathematically determined for the recorded handwritten inputs. Figure 4 shows the physical measurements as well as the feature extraction process. Examples of statistics are total recording time Total, average writing speed in the horizontal direction (V_x) or in the vertical direction (V_y). Statistical evaluation of the measuring signals allows determining various quantities, which in the context of the research work of the authors was identified and implemented in the evaluation system of 69 different characteristics [20].

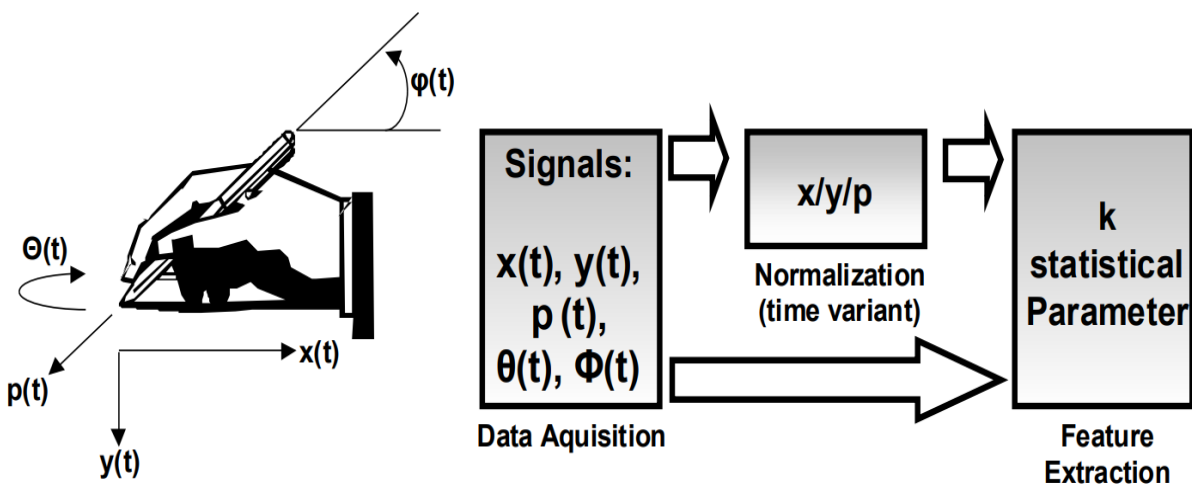


Figure 4. Extraction of statistical characteristics from writing signals

Source: [13]

The transfer of forensic signs of writing to biometric handwriting recognition is discussed in more detail below. As mentioned earlier, when photographing manuscripts using a computer and appropriate equipment, important values can be recorded. These include the position (X, Y coordinates),

pressure and angle of a pen at a specific time. From these values, it is possible to calculate other dynamic quantities, such as writing speed or acceleration [21; 22]. Portability of forensic signs to biometric is not possible for any size to use for user authentication. For example, characteristics

that require a school template may be excluded. This is the case where writing performance needs to be checked for deviations against the school pattern [23].

The force of pressure while writing is part of a test. It indicates how hard the nib was pressed against the font mat while writing. First, the pressure with which the writing is made is considered. For this, the average pressure of all overlap points is calculated. Overlap points are exactly those points that occur when a pen is pressed against the medium of the font, in this case, the digitising tablet, at the beginning of writing performance or after writing inside letters or words. Another component of the pressure force

is the release pressure, that is, the pressure that is at the last point before termination [24; 25].

The angle of the font in relation to a specific line is called the line guide. It is studied in forensics while considering direction of travel. To determine them, the base angle of the font is analysed. The baseline is the main horizontal direction of propagation of the sample font, where the angle of deviation from the horizontal is used as the dimension size, as shown in Figure 5. Mathematically, this size can be determined by direct regression on the number of x/y points occurring during writing, but this assumes heights/sides of font image that is well below one.

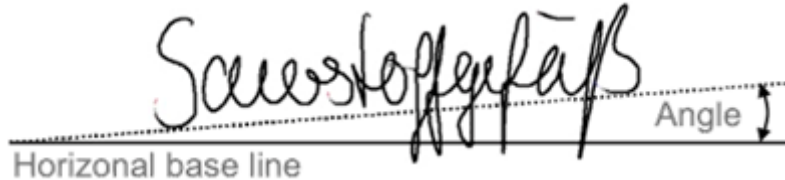


Figure 5. Basic angle definition

A person's font size can be different in different font samples. However, most often the size ratios are very consistent. Size proportion is one of the features of vertical expansion. To determine the proportions, the font sample is divided into three equal horizontal regions. The points are then determined in these areas and the percentage of the total points is calculated. These three values then go into the font sample score as one feature at a time. Horizontal proportions of size. This characteristic was not directly derived from the graphic components of the forensic study of writing. The role model is the vertical proportion of size, as described above. However, with horizontal size proportions, the font sample is split perpendicularly into two areas of equal size [26]. A score is then determined for each area. Again, the ratio of the scores of the two intervals

to the total score is indicated as a percentage. Secondary spacing indicates letter spacing in forensic handwritten research.

Since there is currently no way to extract letters in the foundation behind this article, individual segments are being studied. The evaluation of the detected font features was determined using a specific biometric verification method (bio-hash), which, from a set of vector features of a fixed value n, determines the biometric hash value, also with the dimension N. Detailed information on the algorithm used can be found in [8]. The aim of the study is to identify the influence of the use of forensically grounded quantitative features in comparison with forensically not grounded values for the verification algorithm. For this, two sets of characteristics were used, shown in Table 1.

Table 1. Forensic and non-forensic characteristics

Forensic characteristics		Non-forensic characteristics	
No.	Description	No.	Description
1	average standardised changeover pressure	1	total number of writing points
2	standardised mean steady pressure	2	average writing speed
3	the angle between the direction of propagation of font and a horizontal line	3	number of segments
4	number of points in the zone in percent	4	lowest absolute X-writing speed
5	number of points in the central zone in percentage	5	lowest absolute Y writing speed
6	number of points in the upper zone in percent	6	center of gravity of the horizontal position of a pen in relation to the total horizontal font width
7	number of dots on the left side as a percentage	7	center of gravity of the vertical position of a pen in relation to the total vertical
8	number of dots to the right, in percent	8	font heights
9	ratio between the area of a convex hull and a surface that limits writing	9	normalised center of gravity distance from origin
10	the ratio between the area of the convexity of a character and the area of the convexity of a common font	10	normalised horizontal elevation of the center of gravity to the origin

The test base is an online handwriting test scoring system presented in [8], which is briefly summarised here. The database contains samples of fonts recorded with various digitising tablets. Overall, in most cases studied, there is a significant improvement in detection rate. The absolute value of the error seems to be very high at the level of 23-54%, however, when interpreting it, it should be noted that the examination was carried out everywhere and the optimisation of procedural parameters was not included in the study.

CONCLUSIONS

In general, this work has shown that forensic and biometric characteristics can, in principle, complement each other when solving the problem of automatic biometric user authentication. Despite the fact that not all aspects arising

from the forensic study of writing can be simultaneously implemented for biometric verification of writing, the authors were able to determine a forensic set of features for use in biometrics and compare it with features based on non-forensic characteristics.

The experimental results suggest that, although the frequency of detecting errors in recognition has been improved for all classes of semantics, they are especially pronounced for the most common category – signatures. However, it should be borne in mind that the first authors' study initially examined the global impact on biometric verification without going into the specific effects of physically different input devices. In the future, it is recommended to use approaches that take into account hardware dependencies. In addition, comparison with additional, non-forensic features is necessary.

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