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# **The Use of Mathematical Modeling in the Criminalistics Expert Examination**

**The Author's Abstract**

of the Doctoral Thesis Nominated for Academic Degree  
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#### GENERAL DESCRIPTION OF WORK

**Topicality of research.** Forensic science contributes to the effectiveness and promptness of to be performed by the judicial and investigative bodies. It is intended to develop and implement various scientific methods, techniques and tools for detecting, fixing and investigating evidences and crime. Through this, criminology helps the judicial and investigative bodies to fight crime more effectively and to make the investigations in criminal cases more organized.

In the process of conducting criminalistics-technical expert examination, there are used different types of modeling techniques and methods. There are distinguished three main directions of modeling in the world. These are: physical modeling, simulation modeling and mathematical modeling. In general, modeling is a schematic description of certain processes that allow us for predicting patterns of certain events and characteristics of numerical values. All three models are used at forensics.

For this purpose, such areas of criminal investigation technique were practiced as: forensic photography, trace evidence analysis, forensic ballistics, technical-criminalistics expert examination of documents, and so on. Of these, one of the key field of forensic science is forensic examination of graphology (science of handwriting), whose task is to analyze the handwriting, that is, the graphology. Based on forensic examination of graphology, it is possible identify personality on the basis of handwriting, the person's handwriting style, his identity and the personal qualities. Since the handwriting reveals the true qualities of the personality, including emotional background, fears, frankness, protective response, etc. The expert of the science of handwritings, or graphologists, determine the authors of the handwritings according to their records. Therefore, the role of the criminalistics expert examination is very important for the ascertainment of the truth in a criminal case and objective investigation. The research we performed within the proposed dissertation steers towards increasing the effectiveness, speed and reliability of the works to be executed by carried out by the judicial and investigative bodies on the Georgian handwritings as the controversial documents, and that is why topicality of this research is beyond the questions.

**Aim of research.** The research is aimed at developing and studying the models for indicating and differentiating the gender of the author according to the controversial document executed in the form of Georgian handwriting.

as well as determining its reliability.

**The main objectives of research.** To attain this aim, the following objectives have been set out:

1. To analyze the form and performance peculiarities of the Georgian alphabet in terms of forensic research.
2. To study the peculiarities of the Georgian hand-written texts performed by man and woman and create the models of studying deviations from the standard of the individually performed hand-written alphabet.
3. To carry out the model study of the alphabet in the Georgian hand-written texts executed by woman and man, and to propose the gender differentiation coefficient according to the handwriting.
4. To identify the type of distribution of the gender differentiation coefficient for men and women.
5. To choose the alphabetic letters, which are more characteristic for identifying the author of the hand-writing text.
6. To develop a model of using the computer technology for identifying the gender of the author according to the Georgian hand-writing text.
7. To develop a model of the reliability of identifying the gender of the author according to the Georgian hand-writing text.

**Practical bearing of work.** The method of identifying the gender of the author according to the Georgian hand-writing text has been developed. The possibilities of using the computer technology and programs for using this method have been developed, which greatly simplifies the process of identifying the author's gender according to the Georgian hand-writing text. The obtained results can be used when studying the various hand-writing texts as the controversial documents.

**Novelty of research.**

- ✓ Based on the statistical study of possible deviations from the standards of individual letters for the Georgian hand-written texts, for the first time there have been developed the models for their studying.
- ✓ By using the models of studying the letters, the different frequencies of deviations from the standards of letters in the hand-written texts have been identified – the so called the gender differentiation coefficient. On the basis of this, there has been developed the criterion for identifying the author's gender belonging. It represents the histogram.
- ✓ It has been established that the ascending histogram is characteristic of the hand-written texts performed by women, and the descending histogram is

typical of men's hand-written texts.

- ✓ It has been revealed that the letters having the round and round-like elements have the increased informativity on the author's gender belonging.
- ✓ Based on the above studies, for the first time, there has been developed the method identifying the gender belonging of the author of the Georgian hand-written text.

**Provisions brought to defense:**

1. The developed model of differentiating gender belonging of the author of the controversial document according to the Georgian hand-writing text.
2. The model of the reliability of differentiating gender belonging of the author of the controversial document according to the Georgian hand-writing text.
3. A simplified model of differentiating gender belonging of the author the Georgian hand-writing text.

**Approbation of work.** The main provisions and results of dissertation have been presented at the third and fourth international scientific conferences held at the Department of Energy and Telecommunications of the Faculty of Technical Engineering of the Akaki Tsereteli State University.

**Publications.** 5 scientific articles on the topic of dissertation have been published by the author in the internationally recognized peer-reviewed scientific journals.

**Volume and Structure of Dissertation.** The proposed work comprises 138 printing pages, and includes Introduction, four chapters, conclusions, list of 48 References and Annex.

**Brief content of dissertation.**

Introduction formulates topicality of research and defines aim and objectives of research and its practical bearing.

**The first chapter** provides an analysis of peculiarities of Georgian script and handwriting. This is necessary to create a model of studying the Georgian letters, by configuration of the letters and their strokes, as well as by the layout of the separate elements of the letters in relation to the lines. The modern Georgian alphabet is divided into four groups: 1. The text line letters, whose graphic elements are located on the writing line; 2. The letters having the superscript parts; 3. The letters having the subscript parts; 4. The letters having the both superscript and subscript parts.

The same section also examines the peculiarities of handwriting in the Georgian hand-written texts, the letter signs differ from each other and consist of different elements:

1. The ovals (large and small);
2. The semi-ovals (right and left ones);
3. Horizontal and vertical strokes;
4. Horizontal paragh;
5. Superscript and subscript strokes;
6. Subscript elements.

During the fast writing, the rule of typical execution of the letters is essentially violated, and there are substantial deviations from their standards. Based on the analysis of the latter, it is possible to create a model for studying a separate letter. Deviation from the standards of the typical Georgian handwriting provides rich graphic analysis and material for conducting the expert review of the Georgian hand-written texts and documents. Based on the above mentioned, there have been developed the model in the form of the algorithm for studying the author's gender belonging according to the Georgian hand-written text (Fig 1).

The second chapter dwells on developing the models for studying the letter signs of the second group of the Georgian handwriting, which is based on the breakdown of the typical execution procedure of each letter and the deviations from their standards at that time. As an example, Figure 2 illustrates the model of the Georgian letter "ბ" with the possible 13 different deviations in the hand-written texts.

In accordance with the model of each letter developed when studying the Georgian hand-written texts, there is determined the existence of each deviation shown in the model, as well as the frequency of its detection. In the hand-written texts executed by men and women, it is possible to identify with different frequencies, the different distinct signs from these deviations, which is the possibility of differentiating the author's gender belonging according to the Georgian hand-written text.

The third chapter dwells on studying the possibility of differentiating the author's gender belonging according to the Georgian hand-written text. For this purpose we conducted the experiments, for which the Georgian language text was prepared; it contains more than 1,500 letters and consists of more than 130 words, the text was performed on a paper of A4 format without a transparent. Experimental hand-written samples were taken from

100 men and 100 women, the text was taken down from dictation, at medium tempo, the author's age during performing the text varied from 18 to 50 years.

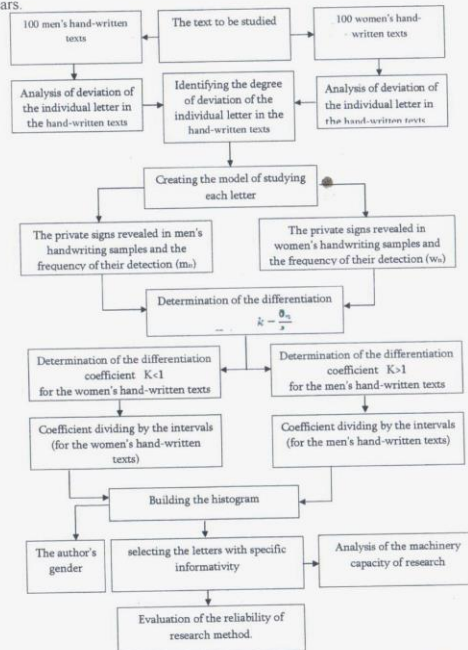


Fig. 1. A model of studying the gender differentiation according to the hand-written texts

1		Performing in a version the «d»-like letter sign
2		Performing in the value twice the line oval of the vertical stroke
3		Performing in the form of the triangle stroke oval
4		The line stroke is elongated towards the horizontal
5		Performing in the form of the semi-oval of the superscript part, with an open part above.
6		Performing in the form of the round motion to the left of the line part
7		Performing in the form of the stepwise motion of the vertical stroke of the letter sign
8		Performing in the straight-line form of the vertical stroke
9		The beginning of the letter sign is located to the right of the vertical stroke
10		The line oval is elongated towards the vertical
11		Performing of the letter begins with the vertical stroke
12		Performing the form of the loping motion around the superscript part
13		The superscript part has a rectangular shape

Fig. 2 A model for studying the Georgian letter „d“, with possible deviations from the standard in thye Georgian hand-written texts

Materials on studying individual samples of handwriting from the mentioned hand-written text are included using the example of a letter “d” in the form of a fragment as indicated in Figure 1 (Annex Table 1), where, in order to fix the private signs of handwriting, the sequence number of the handwritten sample is indicated vertically, but there are located horizontally the graphic figures characteristic of the model of the letter and its sequence numbers

from 1 to 130, the signs are located in Georgian alphabetical order (Table 1, In the full text is given in dissertation)

When studying the hand-written documents, there was also compiled different kinds of Tables, where, while studying each sample of the hand-written text, in case of the presence of sign, in the corresponding box, there was marked “+”, while in the absence of sign, there was marked “-”. The frequency of identifying each sign in each handwriting document, for both performed by men and women, as well as the values of the gender differentiation coefficients (K) are given in Tables

Based on the analysis of the results the research (Table 1), it has been revealed that most of the so-called gender differentiation coefficients calculated in accordance with hand-written texts performed by women are less than 1 ( $K < 1$ ), but in the hand-written texts performed by men, most of the so-called gender differentiation coefficients are more than 1 ( $K > 1$ ). For the practical use of the differentiation coefficient K, for differentiating the gender belonging according to the Georgian hand-written text, it is necessary to carry out additional research, in order to determine the minimum number of  $K < 1$  coefficients, by which we may assume the handwriting was executed by woman. Also, it is necessary to determine the minimum number of  $K > 1$  coefficients, by which we may assume the handwriting was executed by man. For that purpose, there suggested to build the relationship for all  $K < 1$  coefficients K  $< 1$  coefficients and according to the frequency of the corresponding sign (Table 1), which is illustrated by Fig. 3. This relationship has the form of exponent, particularly ascending exponent (with increasing K, the frequency of identifying the private signs is also increasing). Fig. 4 illustrates the relationship built according to the results of research carried out on the hand-written texts performed by men. The relationship has the form of descending exponent (this means that with increasing K, the frequency of identifying the private signs is reduced). The third chapter also suggests the model in the form of algorithm for identifying (predicting) the author’s gender belonging, according to the Georgian hand-written text. It implies that gender differentiation according to the Georgian hand-written text should be carried out in accordance with built exponent, instead of the value of the K coefficient, in particular, if the growth of all  $K < 1$  coefficients is characterized by a tendency in the form of ascending exponent, then it is possible to predict that the author of the hand-written text is female, but if the

growth of all  $K > 1$  coefficients is characterized by a tendency in the form of descending exponent, then we can predict that the author of the author of the hand-written text is male.

**Table 1.** The frequency of private signs and the values of the differentiation coefficients in the hand-written texts performed by men and women

	Name of signs	The frequency of private signs in the hand-written texts performed by women	The frequency of private signs and the values of the differentiation coefficients in the hand-written texts performed by men	The ratio of the differentiation coefficient $s K = \frac{\delta\beta}{\delta\gamma}$
1	The form of performing the initial part of the superscript element of the Georgian letter "ბ", and its direction - arc-like, right-round.	15	28	18,6
2	The form of performing the initial part of the superscript element of the Georgian letter "ბ", and its direction - loop-like; left-round, turning into the arc-like.	11	27	2,45
3	When performing the letter "ბ" - from the superscript and vertical part, to the right, due to the elimination of the finalized signs.	26	13	0,5
4	The relative value of the superscript element of the letter "ბ" vertically - twice the line element.	10	7	0,7
5	The form of the superscript element of the letter "ბ" - straight-line, angular.	35	14	0,4

The same chapter of dissertation evaluates the reliability of the proposed method for differentiation of the gender belonging of the author of the Georgian hand-written text. Figure 5 illustrates two histograms

simultaneously, characteristic of the hand-written texts performed by men and women. When predicting the author's gender belonging according to the Georgian hand-written texts, regardless the value of the the differentiation coefficient, there may occur some inaccuracy, that is, the  $K < 1$  coefficient may appear in the hand-written text performed by man, as well as the  $K > 1$  coefficient may appear in the hand-written text performed by woman, the law of distribution of wrong indicators has a normal form (Figure 5). In its left part, we encounter the private signs ( $\beta\eta$ ) of the hand-written texts mostly performed by woman, for which  $K < 0$ , and in its right part, we encounter the private signs ( $\delta\eta$ ) of the hand-written texts mostly performed by man, for which  $K > 1$ . In the left part, we encounter the private signs from the hand-written texts performed by man, for which  $K > 1$ , and the private signs from the hand-written texts performed by women appeared in the right part, for which  $K > 1$ . According to this inaccuracy, there was filled the so-called reliability determination matrix (Table 3), according to which the reliability of differentiation of the author's gender belonging has been determined by the Georgian hand-written text.

**Table 2**  
Reliability evaluation matrix

$\sum_{i=1}^n X_i = 100$	Coefficients for women 80+(16+4)	Coefficients for men 89+(5+6)	D
♂ double-non-reliable male coefficient	16	5	0,97
♀ double-non-reliable female coefficient	4	6	0,90

The third chapter also proposes the model (algorithm) for differentiating the author's gender belonging according to the Georgian hand-written text (Fig. 6).

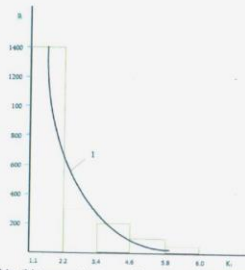


Fig. 3. The relationship (histogram) between the gender differentiation coefficient  $K_m$  of the author of the handwritten text and the frequency of its detection  $n$  ( $K_m$  – men's differentiation coefficient); empirical relationship between 1- $K_m$  coefficient and frequency  $n$ .

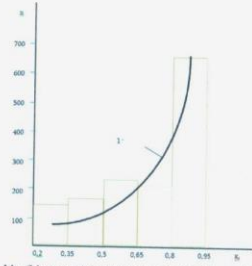


Fig. 4. The relationship (histogram) between the gender differentiation coefficient  $K_m$  of the author of the handwritten text and the frequency of its detection  $n$  ( $K_w$  – women's differentiation coefficient); empirical relationship between 1- $K_w$  coefficient and frequency  $n$ .

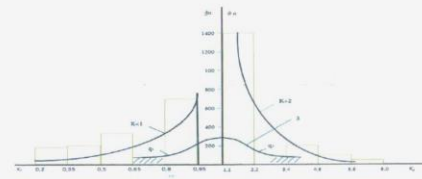


Fig. 5. The histograms built in accordance with the hand-written texts and the inaccuracy distribution dependence.

1- Empirical exponent characteristic of the women's hand-written texts; 2 - Empirical exponent characteristic of the men's hand-written texts; 3 - Inaccuracy distribution curve

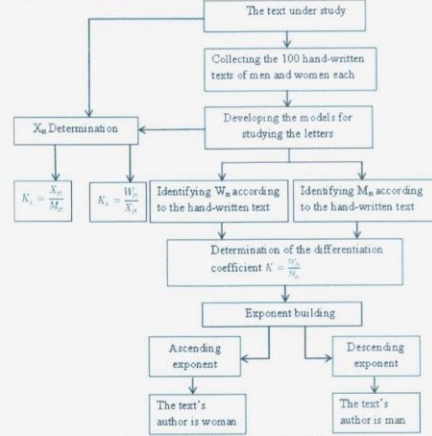


Fig. 6. An algorithm of the gender differentiation

The fourth chapter describes a simplified model of identifying the author according to the Georgian hand-written text. The creation of this model is based on the fact that there have been identified 12 Georgian alphabetical letters having the round or round-like elements, these are:  $\delta, \delta, \varrho, \vartheta, \sigma, \bar{\sigma}, \bar{\sigma}, \bar{\sigma}, \bar{\sigma}, \bar{\sigma}, \bar{\sigma}, \bar{\sigma}$ .

The informativity of identifying the gender of the author of the hand-written text does not actually differ from the informativity of the Georgian 33 alphabetical letters, which is indicated by the actual identity of histograms and empirical exponents built on the basis of their analysis (Fig. 7, Fig. 8).

The fourth chapter also describes the possibility of using the so-called Support Vector Machine developed to identify the author of the Georgian hand-written text, according to the developed model, using a computer program, which will significantly simplify the process of the author's gender differentiation according to the hand-written text.

The process of expert examination of the hand-written text involves: scanning and pre-processing the hand-written text samples; determining the values of the parameters and defining the personal characteristics.

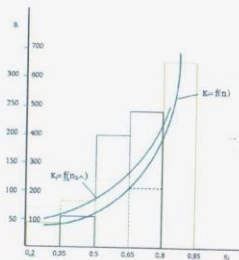


Fig. 7. The relationship (histogram) between the differentiation coefficient for the letters with specific informativity for women and the frequency of its detection ( $n_{n,1}$ ) (the dotted line shows the relationship, when the coefficient ( $K_n$ ) is taken into consideration for all letters of the hand-written text)

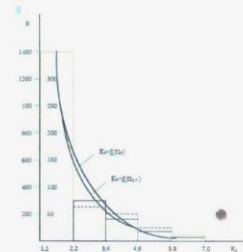


Fig. 8. The relationship (histogram) between the differentiation coefficient for the letters with specific informativity for men and the frequency of its detection ( $n_{n,1}$ ) (the dotted line shows the relationship, when the coefficient ( $K_n$ ) is taken into consideration for all letters of the hand-written text)

## Conclusions

1. Studies have shown that forensic processing of the Georgian hand-written texts allows for identifying the author's gender belonging. As a the gender distinct criterion, there can be used the so-called differentiation coefficient.
2. Comparative analysis of the same Georgian hand-written texts performed by men and women, as well as taking into consideration the deviations from the standards characteristic of Georgian letters in the hand-written texts, there has been worked out the model of studying each Georgian alphabetical letter, by means of which there have been identified in the hand-written texts 130 the so-called observation private and 40 general signs.
3. For comparing the private signs of woman ( $w_n$ ) and man ( $\bar{\sigma}_n$ ) and the same hand-written texts performed by women and men, there has been introduced the distinctive criterion the so-called differentiation coefficient  $K = \frac{w_n}{\bar{\sigma}_n}$ , in order to reveal that  $K < 1$  is characteristic of the hand-written texts performed by women, and shown to be characterized by women's manuscript, and  $K > 1$  – of the texts performed by men.
4. Based on the analysis of the values of the differentiation coefficients and mathematical statistical methods of their frequencies, it has been established



that they are related to each other in the form of exponent. In addition, women's hand-written texts are characterized by fatigue exponent.

5. There has been proposed the matrix method for evaluating the reliability of identifying the author's gender belonging according to the hand-written text, and it has been established that it equals  $\approx 0.8$ . Further increase of reliability is possible, if the differentiation of the author's gender belonging is carried out not by the value of the individual coefficient (for women  $K < 1$ , and  $K > 1$  for men), but also by taking into consideration the frequency of their identification, using exponent.

6. There have been developed the algorithms of research and differentiation for identifying the gender belong of the author of the Georgian hand-written texts. It is proposed to build exponent for gender differentiation according to the hand-written text and to identify the author's gender belonging according to its form.

7. There has been developed a simplified model of identifying gender belonging of the author of the Georgian hand-written text. According to this model, to identify the author's gender belonging, it is sufficient to analyze only instead of all 33 letters of the gender for the sake of sex, it is sufficient to analyze only 12 letters having the round or round-like elements, instead of all 33 Georgian alphabetical letters.

8. By using a simplified model of identifying gender belonging of the author of the Georgian hand-written text, the process of identification may be implemented by means of the computer technology and special programs, using the so called Support Vector Machine.

**The following 5 scientific articles on the topic of dissertation have been published the author:**

1. N. Kopaliani, R. Pilia, D. Dzadzamia, V. Gogisvanidze, The capacities of drawing and sound creation through the mathematical modeling in a Mathcad environment. Periodical scientific journal "NOVATSIYA", No 15, Kutaisi, pp. 56-61
2. Khurtsilava, I. Chedia, Z. Mardaleishvili, R. Pilia. Some aspects of designing the experimental-mathematical model of interaction with a lead object. Georgian Scientific News (GSN) 2011 No 9 (9). 7-11 p.
3. R. Pilia, M. Gorgodze, M. Gokadze, M. Shalamberidze. Identifying the author's gender according to the Georgian hand-written text. - Georgian Engineering News, Tbilisi, 2018. N1, pp.117-121
4. R. Pilia, L. Zivzivadze, M. Gokadze, M. Shalamberidze. A simplified model of identifying the author's gender according to the Georgian hand-written text. - Georgian Engineering News, Tbilisi, 2018 N1, pp.122-127
5. Ormocadze N.S, Bibileishvili D.V, Pilia R.M.- "Specifics of paper-conductive trac-forming mechanism of office equipment". Kutaisi 2013, A.Tsereteli State University II International Scientific Conference Publications Works 2013., pp.235-238