



Postproceedings of the 10th Annual International Conference on Biologically Inspired Cognitive Architectures, BICA 2019 (Tenth Annual Meeting of the BICA Society)

Computational model for forensic biological hair analysis

Denis Nikonets^a, Sergey Kulik^{b*}, Elena Suchkova^c

^aMRFK LTD, Vostochnaya st. 10/1, Gorki Leninskie, Moscow region, 142712, Russia

^bNational Research Nuclear University MEPhI, Kashirskoe shosse 31, Moscow 115409, Russia

^cForensic Center of the MIA of Russia, Z. and A. Kosmodemyanskiy st. 5, Moscow 125130, Russia

Abstract

Human hair is one of the subjects, which is dealt with in researches of the forensic biological examination. To increase the efficiency of evaluating the results of a forensic microscopical analysis of hair from a person's head, in the course of this work, a mathematical model was developed for obtaining a probabilistic-statistical evaluation of the set of matching features, characterizing human hair (the random match probability). Such probability has been estimated for all hair samples from control dataset. As a result of the work, we can conclude that in most cases the estimation of the probability of appearance of the hair features set doesn't give us the precise results which allow to make an unequivocal positive conclusion in the identification of a person by hair. This made it possible to increase the efficiency of forensic biological experts.

© 2020 The Authors. Published by Elsevier B.V.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>)

Peer-review under responsibility of the scientific committee of the 10th Annual International Conference on Biologically Inspired Cognitive Architectures.

Keywords: Forensic identification; microscopical hair analysis; forensic biological examination; probability evaluation;

* Corresponding author. Tel.: +7- 495-788-5699.

E-mail address: sedmik@mail.ru

1. Introduction

Hair is the most common type of evidence among all the biological evidence found at crime scenes. Therefore, it is so important to obtain maximum information about the detected hair and it is necessary to improve the efficiency of the expert biologists, who provide the forensic examination of hair. This is especially important in the absence of other physical evidence.

The forensic examination of the human hair includes a microscopical analysis of their morphological characteristics. When performing a forensic biological examination, investigated hair, found at the crime scene, must be compared with samples of hair of the suspect person (at least 10 hairs from each of the 5 areas of his head: frontal, parietal, right temporal, left temporal, occipital). If all individual micromorphological features of the presented hair and suspect hair samples coincide, it is concluded that the hair under study may have originated from the person being tested. A categorically negative conclusion is formulated if, at least, one of the individual features does not coincide. For forensic analysis of the human hair, the question arises: is it possible to achieve such level of probability occurrence of detected features in which experts can formulate a conclusion about the identification of the person by hair and evaluate the probability of the origin of the hair from the suspect person? Thus, it was decided to develop a computational model to evaluate the probability of a set of the matching features in the investigated hair object and comparative hair samples. The result of our work is important for the improving of the efficiency of the forensic biological examination.

Special methods and models have been successfully used to solve various tasks (including the forensic problems). Here are examples of models and methods applied in various fields: artificial intelligence [1] to criminology, intellectual technologies for decision-making support [2], Bayesian network for accident risks assessment [3], neural network model for forensic handwriting expert [4–6] and information security for Internet of Things [7], special model [8] for cognitive technology [9], three-tier model for structuring of scientific and technical information [10] and agent technologies [11]. In this article, we describe some forensic techniques.

Therefore, the article is organized in the following way: Firstly, the micromorphological features of human hair are introduced in Section 2. The section contains the descriptions of the main groups of micromorphological features of human hair and dataset of hair samples. Secondly, computational model for forensic biological hair analysis is introduced in Section 3. The section describes a computational model for the evaluating of the probability of a set of the matching features in the investigated hair object and comparative hair samples. Finally, main research results are presented.

2. Micromorphological characteristics of human hair

For microscopical analysis of human hair, it is necessary to choose features that characterize a particular person (specific to him) and have the ability to be repeated many times in his hair. It is also necessary that the features are sufficiently resistant to external influences and do not change over time.

86 such features of the human hair were chosen. They belong to 12 groups: 6 groups of the main (individualizing) features and 6 groups of additional features. In our research, we used the following groups of main micromorphological features of human hair:

- Cuticle scale pattern.
- Cortical layer background color.
- Pigment color.
- Pigment granule size.
- Pigment aggregate size.
- Pigment distribution.

Studies have shown [12, 13] that the necessary conditions are fulfilled for the main features. The set of features is stable for different parts of one hair and for all other hair from the head of one person. Earlier studies have shown that the main micromorphological features of hair from the human head have not changed for 12 years. There is also

evidence that the effects of low temperature and ultraviolet irradiation do not exclude the possibility of establishing the origin of the investigated hair from a particular person [12].

To obtain an evaluation of the probability of coincidence of feature sets, a special sample of experimental data is required. In the course of the current study, the dataset of hair samples was formed. Hair samples of 450 men and women of different ages (from 7 months to 90 years) living in different regions of the Russian Federation were used for this purpose. 50 hairs from the head of each donor were examined (10 hairs from each head region: frontal, parietal, right temporal, left temporal, occipital), in total 22 500 hairs were considered [12, 13].

3. Computational model for the evaluating of the probability of a set of the matching features

To develop a computational model for evaluation of the probability of a set of the matching features in the investigated hair object and comparative hair samples (random match probability) traditional approach was used. This approach was developed and widely applied in forensic science in the USSR and Russia — method of evaluating the probability of a set of features. The problem of obtaining a probabilistic evaluation of the matching particular features characterizing the hair is formulated as follows [5, 6, 14, 15]:

Assume that the expert identified in two investigated hair samples n matching features

$$S = \{\theta_1, \dots, \theta_n\}.$$

It is required to evaluate the probability $P(S)$ of such a feature set S . To do this we shall use upper limit of the one-sided confidence interval $P_*(S)$ as an evaluation of the probability $P(S)$, i.e.

$$P\{P(S) \leq P_*(S)\} = \mu,$$

where μ — given level of confidence. Typically, the value $\mu = 0.99$ can be used.

The evaluation of the probability for such set of features $P_*(S)$ must be compared with a given probability value (threshold) Q . If the probability of occurrence of this set of features is less or equal to the specified value, i.e.

$$P_*(S) \leq Q,$$

then the decision is taken about the identification of the person by hair. The value of the threshold Q must be low enough to reduce of the error probability. The choice of the threshold value Q will be considered in further studies.

To obtain $P_*(S)$ we can use interval estimates p_{*i} of probabilities of the corresponding features appearance p_i , i.e.

$$P\{p_i \leq p_{*i}\} = \gamma,$$

where $i = 1 \div n$ and γ — given level of confidence. In view of the assumption about statistical independence of features θ_i , where $i = 1 \div n$, interval estimation of the probability of features set occurrence will be equal to

$$P_*(S) = \prod_{i=1}^n p_{*i}.$$

Thus, it is necessary to find the upper limit of the one-sided confidence interval p_{*i} for an unknown probability p_i (the parameter p of a Binomial distribution or one-sided confidence interval for Binomial proportions) with level of confidence γ :

$$\gamma = \sqrt[n]{\mu}.$$

To find p_{*i} different known variants of approximation of the Binomial distribution can be used [5, 6, 15].

The probability has been estimated for all 86 morphological features, characterizing the human hair. In addition, the evaluation of the probability of features set occurrence $P_*(S)$ has been estimated for all hair samples in control dataset. The minimum value of the probability is $P_{min} = 7.7 \cdot 10^{-7}$, the maximum value is $P_{max} = 2.9 \cdot 10^{-2}$ and the average value is $P_{avg} = 2.2 \cdot 10^{-5}$.

4. Conclusion

To increase the efficiency of evaluating the results of a forensic microscopical analysis of hair from a person's head, in the course of this work, a mathematical model was developed for obtaining a probabilistic-statistical estimation of the set of matching features, characterizing human hair (the random match probability). Our results are useful for forensic experts and students from a broad range of disciplines related to intelligent technologies, for forensic microscopical hair analysis and other fields. The probability has been estimated for all morphological features, characterizing the human hair. In addition, the evaluation of the probability of the features set has been estimated for control dataset of hair samples. As a result of the work, we can conclude that in most cases the estimation of the probability of appearance of the hair features set doesn't give us the precise results which allow to make an unequivocal positive conclusion in the identification of a person by hair.

The plan for future research is to develop the automated workplace for the forensic biologist, which will increase efficiency of work of the forensic expert.

References

- [1] Yasnitsky, L.N., Vauleva, S.V., Safonova, D.N., and Cherepanov, F.M. (2015) "The use of artificial intelligence methods in the analysis of serial killers' personal characteristics." *Criminology Journal of Baikal National University of Economics and Law* **9(3)**: 423–430.
- [2] Borisov, V.V. (2014) "Hybridization of Intellectual Technologies for Analytical Tasks of Decision-Making Support." *Journal of Computer Engineering and Informatics* **2(1)**: 11–19.
- [3] Zaharov, A.S., Borisov, V.V., and Senkov, A.V. (2016) "Accident Risks Assessment by Temporal Fuzzy Bayesian Network." *International Journal of Applied Engineering Research* **11(22)**: 10731–10736.
- [4] Galushkin, A.I. (2007) *Neural networks theory*, Berlin, Heidelberg: Springer.
- [5] Nikonets, D.A. (2009) "Using neural networks in forensic writer identification." *Neurocomputers: design and application* **4**: 26–45.
- [6] Kulik, S.D., and Nikonets, D.A. (2009) "Examples of application of the neural networks in techniques for the forensic handwriting expert." *Neurocomputers: design and application* **9**: 61–85.
- [7] Miloslavskaya, N., and Tolstoy, A. (2017) "Ensuring Information Security for Internet of Things." *IEEE 5th International Conference on Future Internet of Things and Cloud (FiCloud), Prague, Czech Republic*: 62–69.
- [8] Ushakov, V.L., Alexei, V., and Samsonovich, A.V. (2015) "Toward a BICA-Model-Based Study of Cognition Using Brain Imaging Techniques." *Procedia Computer Science* **71**: 254–264.
- [9] Stocco, A., Lebiere, C., and Samsonovich, A.V. (2010) "The B-I-C-A of biologically inspired cognitive architectures." *International Journal of Machine Consciousness* **2 (2)**: 171–192.
- [10] Artamonov, A.A., Ananieva, A.G., Tretyakov, E.S., Kshnyakov, D.O., Onykiy, B.N., and Pronicheva, L.V. (2016) "A three-tier model for structuring of scientific and technical information." *Journal of Digital Information Management* **14(3)**: 184–193.
- [11] Artamonov, A.A., Ionkina, K.V., Kirichenko, A.V., Lopatina, E.O., Tretyakov, E.S., and Cherkasskiy, A.I. (2018) "Agent-based search in social networks." *International Journal of Civil Engineering and Technology* **9(13)**: 28–35.
- [12] Suchkova, E.V., Kulik, S.D., and Nikonets, D.A. (2019) "Evaluation of the possibility of statistical processing of the results of the forensic microscopical analysis of the human hair." *Legal science and practice: journal of Nizhny Novgorod academy of the Ministry of internal affairs of Russia* **2(46)**: 164–169.
- [13] Suchkova, E.V., Kulik, S.D., and Nikonets, D.A. (2017) "Statistical evaluation of results of the study of morphological characteristics of hair from the head of a human in forensic examination." *Criminalist's library. Scientific journal* **6(35)**: 231–235.
- [14] Kulik, S.D., Chelysheff, M.M., Levitsky, A.B., Bazhakin, G.A., Belousova, O.D. et al. (1990) *The Technique of Probabilistic-Statistical Evaluation of the Matched Individual Handwriting Features in Capital Letters of the Russian Alphabet*, Moscow, VNII MIA of USSR.
- [15] Kulik, S.D., and Nikonets, D.A. (2016) "Forensic handwriting examination and human factors: improving the practice through automation and expert training." In: *Proceedings of the third international conference on digital information processing, data mining, and wireless communications, DIPDMWC 2016, 06–08 July*: 221–226.