The Application of Multimodal Analysis of Biometric Data in Forensic Medical Expertise

Radovan Anđelković[1], Milja Knežević[2], Milesa Srećković[3], Radovan Radovanović[4], Radivoje Anđelković[5], Dragan Knežević[6],

***Abstract*—Forensic medical expertise uses a large number of biometric data in the process of making findings and opinions. Further development of biometric analysis leads towards much more specific results that enable more precise identification of persons. Medical documentation contains a large number of biometric data that can be used in forensic medical expertise. In cases where it is not possible to make a precise conclusion based on only one biometric data, multimodal analyzes that take into account several types of biometric data are applied.**

***Index Terms*—forensic medical expertise, biometrics, multimodal analysis.**

I. Introduction

The Law on Criminal Procedure defines that expert testimony as an evidentiary action is performed when, in order to establish or evaluate an important fact, a finding and opinion must be obtained from a person who possesses the necessary professional knowledge, and an expert is a person who possesses the necessary professional knowledge to establish or evaluate a fact in the proceedings [1]. When the subject of expertise is in the domain of medicine (life, health, integrity and dignity of the person), then it is forensic expertise (expertisis medicoforensis) [2]. Forensic expertise can include a large number of procedures and actions aimed at collecting and analyzing biometric data that are later used to provide the findings and opinions of forensic experts. If only one characteristic is compared, it is a unimodal analysis, and if several of these characteristics are compared, then it is a multimodal analysis.

1Radovan Anđelković – Kriminalističko policijski univerzitet, Cara Dušana 196, 11000 Beograd, Srbija (e-mail: radovanandjelkovic847@gmail.com)

2Milja Knežević – Medicinski fakultet, Univerzitet u Beogradu, dr Subotića starijeg 8, 11000 Beograd, Srbija (e-mail:jamilja01@gmail.com)

3Milesa Srećković – Elektrotehnički fakultet, Univerzitet u Beogradu, Bulevar kalja Aleksandra 73, 11000 Beograd, Srbija (e-mail: esreckov@etf.bg.ac.rs)

4Radovan Radovanović – Kriminalističko policijski univerzitet, Cara Dušana 196, 11000 Beograd, Srbija (e-mail: radovan.radovanovic@kpu.edu.rs),

5Radivoje Anđelković – Uprava za vojno zdravstvo MO RS, Crnotravska 17, 11000 Beograd, Srbija (e-mail: zdravstvo@mod.gov.rs),

6Војнотехнички институт у Београду, Ратка Ресановића 1, 11030 Београд, Србија (e-mail: dragan.knezevic@vti.vs.rs), ORCID ID 0000-0003-0624-5474).

Biometric methods were developed for the purpose of reliable identification of humans, but in parallel also for recognizing animals based on physical characteristics or behavioral signs. This method should identify individuals reliably and permanently with no adverse effects on the samples - regardless of whether it is humans or animals. The fact is that traditional methods of marking (branding that causes stress due to heat, cold or chemical effects, then: tattooing, finger cutting, ear piercing and other types of marking) in veterinary medicine have a bad effect on animal behavior and cause harm, which generally gives bad research results and harms animal health. If we dwell on the branding of an animal, it can be seen that its appearance, social interaction, other behaviors and ultimately its survival have been changed, which coincides with sociological influences in human society. The analysis of requirements in veterinary medicine led to the conclusion that animal biometric identifiers are any measurable, solid and recognizable physical, anatomical or molecular feature that is recognizable as a unique identification or verification feature for defining the identity of an animal [3]. The final definition of the requirements of biometric methods from the aspect of veterinary and human medicine are generally that the methods must be non-invasive, do not cause pain, do not change the appearance, do not have an impact on further behavior and social relations in the population. In veterinary medicine, there is an exception the case where recapture and/or handling of animals is required. From the technical side, it is necessary to use a biometric feature that is easily detected by sensors and converted into a measurable format which is not variable over time.

II. Examples of the Most Frequently Used Biometric Methods

The most commonly used biometric methods refer to visual samples, body mass index, eye characteristics, hand recognition, fingerprints, tone of voice, gait/movement and medical documentation.

Visual patterns refer to the external morphological characteristics of the body and changes on it. This method deals with the structure and surface of the body and its parts. The parts of the body with the largest surface area are covered with skin or hair. In animals, the body surface refers to the

 ISBN 978-86-7466-969-3

surface covered with fur, feathers or scales, as well as horny growths.

When we talk about people, the geometric features of the face are especially highlighted, as one of the oldest methods, and in animals, in addition to comparing the features of the head, the prints on the nose are also compared. This method is unobtrusive, hands-free, continuous and accepted by most users.The modern approach to facial image modeling in the visible spectrum refers to the analysis of the main parts of the face, the analysis of segmented features, neural networks, the theory of elastic graphs and the analysis of multiple resolutions. Reduced impact of variable lighting and mask or photo detection is implied in this approach.

Body mass index is a height-weight indicator of nutrition, which is valid for people over 20 years old.

When we talk about recognition based on the characteristics of the eye, the unique patterns of the iris are considered equally in human and veterinary medicine. Retinal sampling is also used in veterinary medicine. The modern system, in addition to automatic eye color detection, extracts the iris and reliably and accurately classifies eye colors in real time.

The process of automatic iris extraction is illustrated in Fig.1.

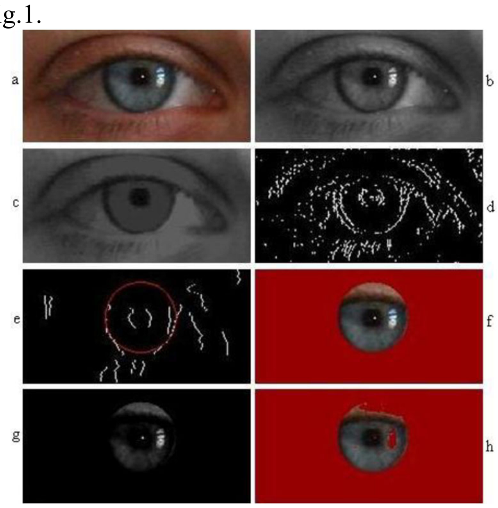


Fig. 1. a. Original image b. Converted to grayscale c. After filling operation d. Detected vertical edges e. Vertical edges after morphological processing and the detected iris circle f. Extracted iris g. Difference image where reflections are highlighted h. Final iris image [4]

Hand recognition has been used for twenty years. It is used for personal authentication. The system measures the physical characteristics of the hand: length, width, thickness and surface area. With this method, there are examples that require a small biometric sample of a few bytes.

Fingerprints fall into unique biometric patterns of ridges and grooves on the fingertips. The key is the small details that are distinguished by some abnormal points on the ridges, such as termination, bifurcation, lake, independent ridge, point, branch and crossing. Although there are different types of minutiae, the two most significant types of minutiae are "termination" which can be characterized as the immediate termination of the ridge and "bifurcation" which is characterized as the point on the ridge where two branches fork [5].

The most common classes of fingerprints are given below and also shown in fig. 2:

• Arch: A fingerprint pattern in which the ridge pattern starts on one side of the pattern and exits on the other side

• Loop: A fingerprint pattern in which the ridge pattern flows inward and returns in the direction of origin.

• Spindle: contains at least one ridge that makes a complete 360-degree path around the center of the fingerprint. Two loops (same as one whole) and two deltas can be found.

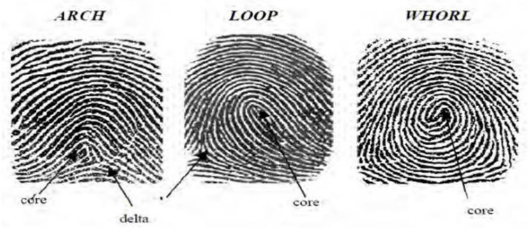


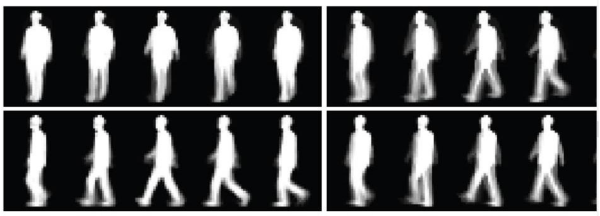
Fig. 2. Fingerprint patterns: arch, loop, and whorl; and core and delta fingerprint landmarks [5]

Two more features used for matching are core and delta shown in fig. 2. The central point on the fingerprint pattern is called the core. The single point from which the three patterns diverge is called the delta. The core and delta positions serve as landmarks for subsequent matching of the two fingerprints.

Although fingerprint-based biometric systems provide positive identification with a high degree of confidence, these biometrics have certain disadvantages compared to other biometrics.

Recognition based on the acoustic characteristics of speech is a non-invasive method and has been used for more than four decades. These traits are related to anatomical features of the throat and mouth and scientific behavioral patterns in terms of voice pitch and speaking style, as a minimum set of traits in this method. These characteristics together represent voice patterns, ie "voice prints". The various technologies used to process and store voiceprints enable voice recognition over long distances either through wired or wireless communication paths. Voice changes over time, due to aging, have an effect on the method.

Recognizable patterns of behavior, which relate to biometric information obtained by walking/moving, reveal the identity, gender, ethnicity and age of the person being observed. Compared to other biometric data, gait/movement is a feature that is sampled from a distance and its characteristics are difficult to mask. In fig. 3 were shows the results of the normalization of gait dynamics into stances of fixed length by means of Viterbi decoding [6]



 ISBN 978-86-7466-969-3

Fig. 3. Normalized dynamics of 18°, 54°, 90° and 126°views, which are extracted from CASIA Gait Database (Dataset B) [7]

Medical data obtained through various analyses, primarily biochemical, hematological, histological radiological, represent key biometric data, including new forms and conditions of patients after surgical interventions. Radiological findings include measurable biometric parameters, such as: cerebral fronto-occipital diameter (FOD), cerebral and bony biparietal diameter (BPD), length of corpus callosum (LCC), height, anteroposterior diameter and area of the vermis, and diameter of the right and left atria. Figure 4 shows a magnetic resonance image of the baby's brain, the size of which is determined based on the position of the fetus in the uterus [8].

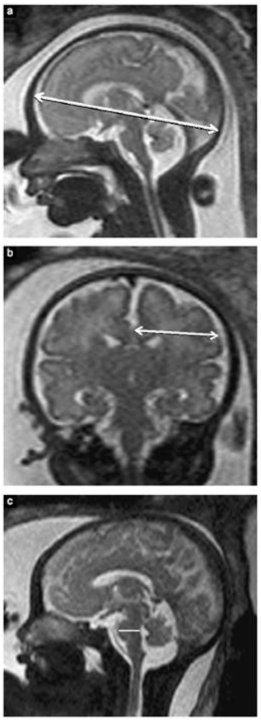


Fig. 4. Midline sagittal T2-weighted magnetic resonance imaging slice, showing measurement of: bone fronto-occipital diameter (a); left cerebral biparietal diameter (b); and anteroposterior diameterof the pons (c) [8]

III. MULTIMODAL ANALYSIS OF BIOMETRIC DATA

Biometrics (Greek: bios - life and metron - measure) can be defined as a method of identifying a specific person based on physical characteristics or certain characteristic behaviors [3,9]. These characteristics should be universal, unique, immutable, accessible and measurable [3,9].

Biometric data is obtained on the basis of biometric analyses. Biometric analyses can be divided into two groups, one group consists of analyses that compare a person's physical characteristics (height, weight, eye color, fingerprint, gender, age...), and the other group consists of analyses that compare behavioral characteristics (gait, voice color, movements in space...).

Medical documentation created during lifetime or obtained through collection and forensic analysis of samples after a person's death can be a source of important biometric data in forensic medical expertise.

Medical documentation about surgical interventions on the body that consequently leave permanent scars on the surface of the skin or tissues located deeper in the body can be important for forensic expertise. Surgical extraction and removal of certain organs (appendix, kidney, spleen, etc.) can be used as an important data source for the identification of a certain person.

The constant improvement of radiological techniques leaves a huge amount of biometric data in the form of digital and analog records of the state of soft and bone tissues (for example, X-rays, digitized data from scanners or magnetic resonance imaging, thermal imaging). X-ray images of bony structures such as teeth and dental rows of the upper and lower jaws have long been used to identify individuals when this is not possible with other techniques. Based on the X-ray image, it is possible to determine the specific shape and structure of the teeth, the interventions that were performed on them, as well as the age of a person, and by combining these data, it is possible to identify the person itself. The similar is the case with X-rays of fractures and injuries that occur under the influence of various bone tissue traumas.

The use of contrast media in radiological imaging enables a better understanding of the structure and organization of soft tissues, as well as the uniqueness of these structures in relation to other people. Here is where contrast angiography stands out, making it possible to determine differences in the anatomical-topographic structure and arrangement of blood vessels, which may be unique to a certain person.

Thermal imaging can determine the topographic arrangement and position of blood vessels that are localized near the surface of the skin, which can also be specific to a certain person.

Analysis of genetic material can be a source of biometric data. The genetic material that is found in the cells and tissues of any organism, and its structure is taken as its unique characteristic. Samples taken by tissue biopsy for pathohistological analysis can be used for genetic matching analyses.

With the progress of medicine and some of its branches, such as transplantation medicine, transplantation of cells, tissues and organs from the donor to the recipient, these procedures are being applied more and more often. Donated cells, tissues and organs can originate from both living and deceased donors. The most common transplants are bone marrow, kidneys, liver, heart, lungs, skin, cornea and hair. The creation of transgenic animals opens up the possibility of animal-derived transplant materials production, which is currently the subject of ethical debates. By carrying out transplantation procedures, one person can carry the genetic material of another person. This can lead to the wrong identification of a person, especially considering that the transplanted cells, tissues and organs in the recipient remain vital even after the death of the donor.

The source of biometric data can be various prosthetic devices, as well as devices that are implanted in the human body during medical procedures. Serial numbers and identification tags found on such devices (pacemakers, insulin pumps, cochlear implants, prosthetic limb extensions, implants used in cosmetic surgery, etc.) allow traceability and determination of who installed them, when and to whom.

During the collection, processing and comparison of biometric data, it should be taken into account that they may change during lifetime. This refers to certain physical characteristics (for example, height, weight, face shape), but also to characteristics related to behavior (handwriting, voice color, typing speed, etc.).

The results of biochemical and hematological analyzes can also be a valuable source of biometric data. This particularly applies to forensic toxicology expertise.

Among the biometric data considered for future application are pulse, body odor, skin composition, nail pattern, gait and ear shape [3,10].

Depending on how many biometric features are used for analysis, they can be divided into unimodal and multimodal. Unimodal analyzes use only one feature for identification and conclusion making, therefore being faster to process, but less reliable. Multimodal analyzes use more biometric characteristics, thus requiring a longer time to process them, but they are also much more reliable.

With the continuous improvement of information technologies, the processing of biometric data is automated, and thus multimodal analysis becomes a better choice. Multimodal analyzes are performed by biometric systems that compare the data of several biometric analyses. The possibility of integrating a huge amount of biometric data obtained from medical records, forensic analyzes and other sources enables better forensic medical expertise.

Multimodal analysis uses biometric characteristics from multiple sources, which is achieved in various ways. Some of them are: the use of multiple sensors for the same biometric feature (for example, optical and capacitive fingerprint sensors), multiple different biometric features (for example, fingerprint and facial features), multiple images of the same biometric feature (to obtain as representative a sample as possible), or using multiple different algorithms of sample processing [11].

IV. Conclusion

The development of information technologies and modern sensor systems enable the collection of a large number of biometric data and their use in forensic medicine. During their collection and processing, medical documentation should be taken into account, making the assessment of the collected data as accurate as possible and a possibility of wrong conclusions as minimal. By applying multimodal analyzes and assessing the reliability of biometric data, the possibility of making wrong findings and opinions by forensic medical expertise is reduced.

Special importance should be given to assessing risks in biometric authentication technology, which are limited to enrollment and identification/verification processes based on biometric algorithms, which are generally considered black boxes. Of particular importance is the systemic holistic security aspect of biometric authentication technologies, both from the point of view of IT security biometrics, and in sampling methods in human and veterinary medicine. In this sense, we are of the opinion that in the modern solution of this problem, biometric authentication risk matrices will show that it is possible to identify individual classes of risk impact.

Acknowledgment

This student paper were supported by Military Medical Academy, Criminal Police University and Serbian Ministry of Science, Technological Development and Innovation in 2023, registration numbers are 451-03-47/2023-01/200325.

References

[1] Zakon o krivičnom postupku, „Službeni glasnik“ broj 72/2011, 101/2011, 121/2012, 32/2013, 45/2013, 55/2014, 35/2019, 62/2021, 27/2021 – odluka Ustavnog suda.
[2] M.Tasić i saradnici, “Судска медицина”, Змај (2006).
[3] U.G.Barron, F.Butler, K.McDonnell, S.Ward: “The end of the identity crisis? Advances in biometric markers for animal identification”, Irish Veterinary Journal, 62, 204- 208 (2009)
[4] A.Dantcheva, N.Erdogmus, J.L.Dugelay, “On the Reliability of Eye Color as a Soft Biometric Trait”, 2011 IEEE Workshop on Applications of Computer Vision (WACV), (2011)
[5] M.Sharma, “Fingerprint Biometric System: A Survey”, International Journal of Computer Science & Engineering Technology (IJCSET), Vol. 5, No. 07, pp 743-747 (2014)
[6] Z.Zhang, M.Hu, Y.Wang, “A Survey of Advances in Biometric Gait Recognition”, Chinese Conference on Biometric Recognition, pp 150-158 (2011)
[7] S.Yu, D.Tan, and T.Tan, “A framework for evaluating the effect of view angle, clothing and carrying condition on gait recognition”, Proc. IEEE/IAPR Int. Conf. Pattern Recog., vol. 4, pp. 441–444 (2006)
[8] B. Tilea et all, “Cerebral biometry in fetal magnetic resonance imaging: new reference data”, Ultrasound in Obstetrics and Gynecology vol. 33(2), pp. 173-81 (200)
[9] D.Stanojlović i saradnici, “Antropološko veštačenje odnosno manuelna biometrija i kkomparativno veštačenje lica”, IUSTITIA, Paragraf lex, Novi Sad, broj 2 (2018)
[10] S.Stojčić i saradnici, “Forenzičke metode za identifikaciju lica: juče, danas, sutra”, Zbornik radova, LXVI Konferencija ETRAN, Novi Pazar (2022)
[11] S.Mesarović, “Multimodalni biometrijski sistemi”, Univerzitet Singidunum, Fakultet za poslovnu informatiku, Magistarska teza, Beograd (2007)

 ISBN 978-86-7466-969-3