INTRODUCTION

In recent times, an increasing number of researchers have been incorporating artificial intelligence into their work [3, 13]. There have been discussions about whether artificial intelligence can become a worthy replacement for medical professionals [6, 12]. Overall, the scientific community believes that such a replacement will not occur in the immediate future, but artificial intelligence can be beneficial for medical practitioners by assisting them in making more objective decisions or even displacing human judgment in certain aspects. With the growing availability of medical data and analytical methods applied to their processing, there have already been successful examples of using artificial intelligence in medicine [4, 5, 6]. Neural network algorithms are widely employed in medical fields such as cardiology, dermatology, immunology, oncology, dentistry, genetics, and others [5, 8, 10, 11]. Forensic medicine is no exception, as elements of artificial intelligence are beginning to be extensively applied in this field [1, 9].

Forensic Medical Identification of Unknown Persons has become one of the primary directions in forensic medicine. This is associated with the armed conflict in Ukraine and all the negative social phenomena accompanying it, such as high mortality rates and the mass appearance of unidentified victims including military personnel from both sides of the conflict as well as civilians. Therefore, innovations in this field are crucial for the Ukrainian community. It is worth noting that in international practice, the organization ICPO-Interpol oversees and facilitates all integration-related professional achievements concerning person identification and the organization of forensic medical examinations. This organization possesses not only intellectual resources but also a range of algorithms developed and adapted for various types of catastrophes [2, 4, 7].
To manage the aftermath of disasters with mass casualties at both international and national levels, Interpol has developed a methodological approach known as Disaster Victim Identification (DVI), which consists of four phases. The first phase of DVI involves conducting a site inspection of the disaster, identifying individuals who perished in possible situations, and establishing the necessary working group responsible for the identification process. An essential element is establishing clear collaboration with the national authorities of the country where the disaster occurred, as well as with international supervisory and coordinating bodies.

The second phase includes collecting post-mortem information, which entails gathering data that can be obtained during the examination of the deceased bodies. These data include DNA, dermatoglyphic prints, dental status characteristics, such as the results of dental targeted and panoramic X-rays.

The third phase involves collecting possible ante-mortem materials (clinical dental examination data, medical records, information from relatives and family, etc.).

The fourth phase consists of analyzing the collected data and issuing results. One of the fundamental methods of DVI Interpol is the method of dermatoglyphic identification, driven by its material efficiency, high informativeness, and the ability to obtain results within a short time frame.

THE AIM OF THE WORK was to justify the feasibility of using neural networks for predicting external identifying characteristics of individuals based on dermatoglyphic parameters. Thus, we aimed to enhance the dermatoglyphic method as a key component of the algorithms within the DVI-Interpol system.

MATERIALS AND METHODS

To conduct this research, dermatoglyphs of the hands and feet were obtained from 567 individuals aged 18 to 59 years, including representatives of both sex — males and females. Specific criteria for inclusion in the study were voluntary consent, absence of genetic pathologies, endocrine system disorders, musculoskeletal issues, and an age range of 18 to 59 years. The scope and methods of the study align with the fundamental principles of the Helsinki Declaration on Biometric Research (1974), adapted at the 41st International Assembly in Hong Kong (1989), where humans are the primary subject. During the study, adherence to basic principles such as respect for the individual, informed consent, and assessment of risk and benefit were ensured.

At the first stage of the research, anthroposcopic and anthropometric parameters were measured and recorded. Anthroposcopic parameters were obtained through questionnaires completed by the subjects. Anthropometric parameters were obtained using standard measuring instruments such as a height meter, a measuring tape, and a protractor. Additionally, anthropometric parameters were categorized into somatometric and craniometric.

At the second stage, dermatoglyphic elements of the hands and feet were obtained. A Futronic FS80 scanner was used to acquire dermatoglyphic parameters, followed by the application of the VeriFinger 6.6/MegaMatcher 4.4 Identification Technology Algorithm [9] to convert raster vector images into graphical objects to improve quality.

At the third stage of the study, univariate and multivariate statistical analysis of the obtained parameters in different ethnic-territorial groups, divided by sex, was conducted. Microsoft® Excel 365 was used for data analysis, where initial parameters and coefficients were computed based on the raw data. The primary software package for statistical analysis was STATISTICA 12 for Windows. During the study, the following were calculated: correlative relationships between anthropometric, anthroposcopic parameters, the type of dermatoglyphic pattern, and the frequency of occurrence of dermatoglyphic patterns, as well as the...
mean arithmetic value ($\bar{X}$), the mean square error of the mean arithmetic value ($S_X$), the standard deviation ($\delta$), Student’s t-distribution, and the probability of error ($P$), Spearman’s rank correlation coefficient. The obtained results served as the basis for training artificial neural networks for the subsequent prediction of external identifying characteristics of individuals.

RESULTS OF THE RESEARCH AND DISCUSSION

Using a variety of neural networks, we have developed the core functionality of the «Dermatoglyphics For Prediction (DFP)» program [Author’s Certificate No. 74561. Computer program «Forensic Medical Identification Program Using Artificial Neural Networks». Registration date 07.11.2017]. This program consists of a core based on neural networks and a user interface primarily constructed from classes like javafx. application.*, javafx.stage.*, java.awt.*, and many other classes from Java Development Kit 1.8. Java FX 8 was employed for creating the graphical interface. This framework enables the rapid and efficient implementation of the graphical representation of the core code. Additionally, it is cross-platform, meaning that programs developed using JavaFX can run on various operating systems. We utilized the JFoenix library to enhance the design and adhere to accepted Material Design standards (Figure 2).

We describe the approach to creating the computer program:

Step 1. Building the neural network. To do this, data needs to be entered into a table, and the Neural Networks menu item should be selected. Detailed instructions can be found at http://statsoft.com.

Step 2. Training the neural network. To conduct training, apart from the input data (in our case, dermatoglyphic parameters of hands and feet) (S, L, ApNu,...), an additional code category should be added, namely «train» for training and «select» for the control subset. Once the target category is selected (Ethnic in our case) and continuous input variables (Cl, ApNp,...) are chosen, there is a choice between three strategies for model construction (ANS — Automated Neural Network, CNN — Custom Neural Network, and Subsampling — Multiple Subset Method). For simplicity, it is advisable to choose the automated neural network. Using the NNSET variable, the training (train) and control (select) sets are defined. Then, the strategy for creating subsets with the following input parameters is selected: 5 random subsets with a relative percentage ratio of 70-15-15 %, training — control — test subsets. Activation functions are chosen as Logistic, Tanh (logistic, hyperbolic) for output neurons and Logistic, Tanh, Exponential (logistic, hyperbolic, exponential) for hidden neurons. Additionally, the output parameters specify the number of hidden neurons (30 to 50), weight decay for neuron weights (from 0.001 to 0.01 for hidden layers), and the number of networks for training (20). These parameters are experimentally determined and can vary within relatively broad ranges depending on the type and complexity of the task [14].

Step 3. Determining network performance. After training, five neural network models with different performance indicators (percentage of correct classification – the closer this number is to 100, the better the model classifies data), training, and testing performance will be obtained.
After obtaining the initial results, the network with the highest training performance can be selected (in our experimental case, a network with an MLP architecture of 24-42-3 (24 input, 42 hidden, 3 output neurons). If the result is unsatisfactory (e.g., 85%, which is quite low), it can be improved by switching to the CNN model, where you can specify refining input data, namely the RBF network type (radial basis function), 20 networks for training, the number of neurons (50), the number of epochs (10,000), and enable interactive training for visual error analysis. Similar operations can be performed until the testing performance and training performance meet your requirements in terms of performance.

Step 4. Selection of the Final Network. To make a correct choice of the final network, one should pay attention not only to testing performance but also to the error matrix. The analysis of the obtained neural network includes the construction of confidence levels for all samples. Additionally, emphasis should be placed on the sensitivity analysis of the variables included in our neural network. The analysis data will indicate that the feature «Wr» of one parameter is more important in prediction than other parameters. Therefore, during further analysis and model tuning, more attention should be directed towards the «Wr» feature. Much information about the network’s classification quality can be obtained from lift charts and various graphs, which can be constructed using the STATISTICA software package.

The application of the developed computer program allows for a quick prediction of the ethnoracial (territorial) affiliation of an unknown individual and the likelihood of the presence of anthropometric parameters based on input data in the form of dermatoglyphic parameters within a short time frame (5-7 minutes).

The proposed program is compatible with all modern operating systems (Windows, Linux, MAC OS, Android) and is written in the Java programming language with the use of Java graphical interface and the JFoenix library.

Below is a step-by-step algorithm for using the developed program:

Step 1. Preparation for Launch. Dermatoglyphics For Prediction (DFP) is an independent software product written in the Java programming language. For the correct operation of the program on a Windows-based operating system, it is necessary to have the Java software — «Java Runtime Environment» (JRE) and «Java Virtual Machine» (JVM) installed on the system. Typically, these modules are included in the standard Windows package. If necessary, they can be downloaded for free from the official Java website [15].

Step 2. Running the DFP Program. The DFP program is an executable file with the.exe extension, which is launched by double-clicking from any storage medium: hard drive, flash drive, or optical disc (DFPv28.exe). As new data is processed, the program is supplemented, and new versions are developed (version as of 01.08.2023 — v28). Depending on the security settings of the operating system, the program can be run by both guest users and device administrators. If the program’s launch is blocked by the Windows security system when run by a guest user, please contact the device administrator.

Step 3. Main Program Window. After launching, the main program window (Figure 4.9) will appear on the screen, containing buttons to navigate to a brief description of dermatoglyphic features with corresponding images (Instruction button) and to a window where dermatoglyphic parameters of the investigated individual need to be entered (Run DFP button) (Figure 3).

Fig. 3. The main window of the DFP program and the program’s workspace

Step 4. Data Entry. After clicking the «Run DFP» button, a window will appear (Figure 3) where you need to enter data. The workspace of the window is divided into two parts — for the right and left hands. These areas are structured like a table, where you need to input data obtained from the palms of the investigated individual into the respective cells. Data from fingerprint patterns on the fingers are selected from the corresponding drop-
down lists. Additionally, in the appropriate drop-down list, you need to select the sex of the investigated individual. The program is designed in such a way that you need to input all the data to obtain results. If any cell is left empty, a prompt will appear in the respective area.

Step 5. Data Processing Results. After entering all the data, you should click the «Submit» button. At this point, the program will process the input data, and the results window will display the predicted outcome, including ethno-territorial affiliation and the confidence interval (Figure4).

![Fig. 4. DFP Results](image)

### CONCLUSIONS

Undoubtedly, the world is not standing still, and the emergence of innovative technologies cannot bypass the field of medicine. The use of computer technologies in the analysis of medical data has a positive impact on research outcomes as it helps eliminate a range of errors associated with human factors. Furthermore, the increasing needs of the Ukrainian community for the identification of unknown individuals in light of the geopolitical situation related to Russian aggression in Ukraine (the constant threat of missile attacks and unmanned aerial vehicles throughout Ukraine, which can lead to mass casualties) justify the relevance and the search for opportunities to improve and modernize the provision of dermatoglyphic identification expertise. This can be achieved through the use of state-of-the-art technologies, specifically neural network forecasting of external recognition features of an unknown individual, based on dermatoglyphic parameters of the hands and feet. This, in turn, will enhance the objectivity and validity of dermatoglyphic forensic medical expertise.

### COMPLIANCE WITH ETHICAL REQUIREMENTS

The scope and methods of the study do not contradict the basic principles of the Declaration of Helsinki for Biomedical Research (1974), adapted at the 41st International Assembly in Hong Kong (September 1989), in which human beings are the subject of research. The study was conducted in compliance with such basic principles as respect for the individual, patient information, and risk-benefit assessment. Compliance with bioethical requirements in scientific research meets the requirements of the Ethics Committee of Ivano-Frankivsk National Medical University.

### AUTHOR’S CONTRIBUTION TO THE ARTICLE

Yulia Z. Kotsiubynska — author of the idea, preparation of the computer program, Volodymyr M. Voloshynovych — substantiation of relevance, translation and editing of the text, Yuriy I. Solodjuk — graphic support, statistical processing of data, Valentyna I. Liampel — literature review on this issue, Vasyl L. Fentsyk — preparation of primary research material.
REFERENCES


Резюме

ШТУЧНИЙ ІНТЕЛЕКТ – ЗАСТОСУВАННЯ У СУДОВІЙ МЕДИЦИНИ
Юлія З. Коцюбинська1, Володимир М. Волошинович1, Юрій І. Солоджук2, Валентина І. Лямпель3, Василь Л. Фенцик4

1 – Івано-Франківський національний медичний університет, кафедра судової медицини, медичного та фармацевтичного права, м. Івано-Франківськ, Україна
2 – Івано-Франківський національний медичний університет, кафедра стоматології післядипломної освіти, м. Івано-Франківськ, Україна
3 – Івано-Франківський науково-дослідний експертно-криміналістичний центр МВС, м. Івано-Франківськ, Україна
4 – ДВНЗ «Ужгородський національний університет», кафедра загальної хірургії з курсом судової медицини, м. Ужгород, Україна

Вступ. Штучні нейронні мережі широко використовуються в медичних галузях, таких як стоматологія, молекулярна генетика, імунологія, кардіологія та інші. Судова медицина також не є виключенням – штучні нейромережі також починають у ній застосовуватися.

Метою цього дослідження було показати можливість прогнозування антропометричних параметрів людини за допомогою дерматогліфічних параметрів, що дозволить покращити метод дерматогліфічної ідентифікації.

Матеріали та методи. Ми використали дерматогліфи рук і ніг від 567 осіб віком від 18 до 59 років, без генетичних або ендокринних захворювань та проблем з опорно-руховим апаратом.

Результати та обговорення. Результатом нашої роботи стала розробка програми «Dermatoglyphics For Prediction (DFP) [Авторське свідоцтво № 74561. Комп’ютерна програма «Судово-медична ідентифікаційна програма з використанням штучних нейронних мереж». Дата реєстрації 07.11.2017]. Даний програмний девайс після відповідного навчання дозволяє прогнозувати етно-територіальну належність та наявність у досліджувані особи певних антропометричних параметрів за використанням таких вихідних даних, як дерматогліфи рук та ніг.

Висновки. Зростаючі потреби української спільноти у ідентифікації невідомої особи з огляду на геополітичну ситуацію пов’язану з російським вторгненням в Україну (постійно існуюча загроза атак балістичними ракетами та безпілотними літаючими апаратами по усій території України, що може бути причиною катастроф із масовими жертвами) обґрунтовує актуальність, пошуку шляхів інновації дерматогліфічної експертизи, за допомогою використання новітніх технологій, а саме нейромережевого прогнозування антропометричних параметрів, статевої та етно-територіальної належності невідомої особи, за використанням таких вихідних параметрів, як дерматогліфи рук та ніг, з метою підвищення доказовості ідентифікаційних експертиз.

Ключові слова: ідентифікація, DVI-Interpol, дерматогліфіка, штучні нейронні мережі