Perspectives of Artificial Intelligence Use in Fingerprint Examination

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The use of AI in fingerprint examination holds a significant potential to enhance its the accuracy, speed and objectivity. At the same time it has a number of weaknesses, which must be considered.

Keywords: *forensic science; artificial intelligence (AI); dactylography; fingerprinting; forensic examination.*

Перспективи застосування штучного інтелекту в дактилоскопічній експертизі

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Застосування штучного інтелекту під час дослідження відбитків пальців має значний потенціал для підвищення його точності, швидкості та об'єктивності. Водночас він має низку слабких характеристик, які необхідно враховувати.

Ключові слова: *судова експертиза; штучний інтелект (ШІ); дактилографія; дактилоскопія; експертне дослідження.*

Forensic science is known to quickly adopt all the most progressive technologies of the time. Nowadays, in the age of information and rapid technological development it sucessfully uses achievments of allied sciences like physics, chemistry, biology etc., and of course, information technologies. One of the most rapidly growing branches of computer science is artificial intelligence (AI), and it opens a huge variety of oppportunities for forensic science in general and dactylography in particular.

Quite a number of modern scientists show interest in AI use for the goals of forensic science, among them are Yung-Fou Chen, Paul Kuei-chi Tseng, Apoorva Singh, Vinay Aseri, Varad Nagar, Sneha Lohar, Poonam Kumari, Surya Shekhar Daga, Mahipal Singh Sankhla, Chandra Shekhar Yadav, Kumud Kant Awasthi, Eman Ahmed Alaa El-Din, Vinny Sharma, Prashant Johri, Chesnokova E.V., Usov A.I., Omel'yanyuk G.G., Nikulina M.V., Hmyz A.I., Dashkov T.K., Domysheva T.V., Comosko A.A. and many others, which highlights the great potential of this technology.

According to Eman Ahmed Alaa El-Din, artificial intelligence (AI) is a branch

of software engineering, concerned with a computer process that can mimic human behavior and thought processes such as learning, reasoning, adapting and self-correction [1].

Yung-Fou Chen and Paul Kuei-chi Tseng note, that AI is a distinct branch of computer science and engineering that concentrates on creating technologies capable of processing information. These technologies employ intricate models and algorithms that can learn and execute cognitive tasks. This allows AI to deliver results such as predictive analysis and decision-making, applicable in both physical and digital environments. A distinguishing characteristic of AI algorithms is their capacity to process data in a manner that is not readily comprehensible to humans, rendering AI a «black box» [2].

While conducting fingerprint examination forensic experts face the necessity to deal with an enormous amount of information, which takes much time, efforts and resources. AI algorithms, particularly those involving machine learning and deep learning, can process large amounts of fingerprint data with higher precision than traditional methods. By learning from vast datasets, AI systems can recognize subtle patterns, inconsistencies and variations.

AI can automate many of the time-consuming, repetitive tasks associated with fingerprint analysis, such as comparing fingerprints found at crime scenes with databases of known prints. That's actually one of the main functions of Automated Fingerprint Identification Systems (AFIS). AFIS are widely used around the world and are built on various algorithmic approaches, including machine learning methods. AI implementation in AFIS has driven advancements such as image enhancement, feature extraction, indexing and matching [3].

AI systems, including AFIS, can be trained on growing databases of fingerprint patterns, continuously improving their accuracy and learning new ways to differentiate between unique patterns. This makes AI a powerful tool for evolving forensic practices, as it can adapt to new challenges and improve over time.

The main differences between the conventional system and the AI system are:

- in the conventional method minutiae are located manually with the help of a magnifying glass, whereas in the AI system the minutiae identification is done using an inbuilt software tool that extracts the ridge characteristics;
- the located minutiae can be stored digitally in unique binary code form in the case of an AI system, whereas this is not possible in conventional methods;
- the conventional method is time consuming and all the minutiae might not necessarily be found, whereas the AI system does this job in seconds;
- conventionally located minutiae can be very confusing if further analysis is done, and probably, if handed over to a new person, the second time, he/she might have to

locate the minutiae again whereas no such issues are encountered in the case of the AI system;
- the chances of error are high in the case of AI systems as software is not always reliable, while manual identification is less prone to errors;
- with the aid of an AI, a large number of samples can be analyzed in a remarkably short amount of time, a system that will further aid law enforcement agencies in a speedy investigation;
- the application of an AI-based system does not necessarily require an expert in fingerprints, as a person who is adequately trained to use the biometric software would fit the purpose. But an opinion can only be formed with the help of an expert in the field of fingerprints [4].

As Kamshad Mohsin emphasizes, when it comes to criminal investigations, AI can be a great tool in many expects like:
- data analysis and availability to support the investigation;
- addressing well-scoped problems and methodology for cases;
- pattern recognition;
- explaining the reasoning process well;
- reducing the level of false-positives or false-negatives during analysis;
- formally structuring the representation of knowledge which will also help the legal community in fast and accurate solution;
- having a well-organized performance evaluation;
- data mining and knowledge discoveries;
- building statistical evidence;
- integrating with current architecture, tools and applications [5].

Thus, the principal strengths of machine learning versus human learning are: that machines can process large amounts of data, find weaker or more complex patterns and work better in less predictable environments; also, machines can be more consistent decision-makers because they are less susceptible to cognitive bias. Alongside with that, major weaknesses include: a lack of model flexibility; not all problems have the correct data to learn; data can reflect bias in the real life; not every problem can be solved with mathematical analysis, which is the only output with machine learning applications; and other considerations must be «factored into decisions», including privacy issues, that AI may not be able to address the same way humans can. Though AI has its positive uses, however, it should not replace the human expert opinion and human judgment as to legal liability because AI and humans arrive at conclusions differently. AI has tremendous potential for improving forensic science practice, but its potential can be only unlocked by starting to address the ethical and legal challenges facing us. Ethical challenges of AI include four primary challenges: informed consent to use; safety and transparency; algorithmic fairness and biases; and data privacy. Legal chal-

lenges of AI focus on safety and effectiveness, liability, data protection and privacy, cyber security, and intellectual property law [1].

AI in forensic fingerprint examination is still a developing field. Research is ongoing to improve the accuracy of AI systems, reduce biases and make these technologies more transparent and explainable. Advances in machine learning, neural networks and image processing are expected to further enhance AI's role in fingerprint analysis.

In the future, AI is likely to be used as a tool to assist human fingerprint examiners, but it would never be able to replace them entirely. AI could provide initial analyses and suggestions, which human experts would then review. This collaborative approach would combine the strengths of both human expertise and AI efficiency, ensuring that the final conclusions are accurate and reliable.

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