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Artificial Intelligence in Forensic Sciences Revolution or Invasion? Part II

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Abstract

Aim: The study is on the emerging role of artificial intelligence in the forensic sciences. After clarifying the basic concepts and a brief historical overview, the possibilities of using AI in various forensic fields are discussed: genetics, pattern recognition, chemistry, toxicology, anthropology, forensic medicine, and scene reconstruction.
Methodology: The study synthesises several recently published international papers.
Findings: The penetration of the application of artificial intelligence into some fields of science is undoubtedly an ongoing process. Most of the varied forensic fields also cannot avoid this development. Analysing large databases unmanageable with traditional methods, pattern recognition, and machine learning can all be important tools for forensic science. However, an important conclusion is that AI is a supporter of human expert work, not a substitute.
Value: In the field of forensic sciences, no such detailed summary article has been published in Hungarian so far.

Keywords: artificial intelligence, forensic science, genetics, anthropology

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Artificial intelligence and fingerprints

A latentfingerprint is formed on the surface by the residue of material left behind by the friction ridge skin. Researchers used desorption electron spray ionisation mass spectrometry (DESI-MSI) to estimate the chemical pattern and structure of latent fingerprints to determine the composition of the material residue, and evaluated using a 'Gradient Boosting Tree' (GDBT) machine learning classification model, which allowed the standard samples tested to be classified by gender, ethnicity and age. This system was able to discriminate and classify uploaded fingerprint samples and determine age, sex and other anthropological characteristics through sweat components. This method may offer significant forensic value in the future, using machine learning of mass spectrometry results to enable the cost-effective identification of certain characteristics of people based on their metabolites left behind at crime scenes. With the development of this method, a futuristic discipline may emerge, namely forensic metabolic fingerprinting (Zhou and Zare, 2017). Note that DESI-MSI is also a method for the develop of latent fingerprints (Ifa, Manicke, Dill & Cooks, 2008; Petrétei, 2023).

Israeli fingerprint expert Ido Hefetz presented his research on 20 September 2023 in Lisbon, at the annual conference of the ENFSI Fingerprint Expert Working Group, in which he attempted to distinguish between male and female fingerprints using an artificial intelligence-based image recognition algorithm. He fed thousands of fingerprints into the machine. The results are not yet conclusive. The same author has also published on the ethical issues of artificial intelligence (AI) in forensic fields (Hefetz, 2023).

AI can also be used to generate a facial image of the donor based on the fingerprint. One study presents a novel approach based on artificial neural networks to generate one biometric feature (the face) from another (fingerprints only) (Ozkaya & Sagiroglu, 2010). An automatic and intelligent system has been designed and developed to analyse the relationships between the fingerprint and the face, and to model and improve the relationships. The new system is the first test to produce all parts of the face, including the eyebrows, eyes, nose, mouth, ears and the border of the face, from fingerprints alone. Parameter settings for the system were made using Taguchi's experimental design technique. The performance and accuracy of the system was evaluated using a ten-fold cross-validation technique, using qualitative evaluation metrics in addition to the extended quantitative evaluation metrics. Consequently, the results are presented using a combination of these objective and subjective metrics to illustrate the qualitative properties of the proposed methods and to quantitatively evaluate their performance. Experimental results showed that one biometric characteristic can be determined from another.

These results show that there is a strong relationship between fingerprints and facial features (Ozkaya & Sagiroglu, 2010; Leone, 2021). Consider that identical twins have fingerprints and facial features that show strong similarities.

AI in other forensic sciences

In 2022, a paper on AI and forensic entomology was published (Apasrawirote et al., 2022). An automatic DCNN (Deep Convolutional Neural Network) method was used to identify different species of fly maggots of forensic importance based on images of the posterior spiracles. The same method can also be used for diatom identification (in case of drowning in living water).

AI has also entered the field of firearm comparison. When a bullet is fired, the weapon leaves microscopic traces on the bullet and the cartridge case. These marks are quasi "ballistic fingerprints". Neural networks guide experts where to look for bullet residue and shell casings, and image processing compares the gunshot wounds and other evidence with the database without manual intervention. Scientists have developed algorithms using a mathematical model (automated ballistics identification system). During experimental firing on a metal plate, these algorithms were able to detect shots, distinguish muzzle blasts from shock waves, determine the timing from shot to shot, determine the number of firearms present, assign specific shots to weapons, and estimate the likely calibre. All of this can assist law enforcement and investigations (Bobbili et al., 2020).

Other researchers have attempted to use deep learning to estimate the range of a shotgun based on the distribution of the shotgun's firing lesions. This conceptual study has demonstrated potential future forensic uses, albeit with some limitations (Oura et al., 2021).

The SHUTTLE project has been funded by the Council of the EU since 2017. The acronym is *Scientific High-throughput and Unified Toolkit for Trace analysis by forensic Laboratories in Europe*. It is essentially a set of automated motorised microscopes and their image analysis algorithms that can quickly and efficiently identify relevant lesions, such as elementary fibres (URL1), captured by the microscope. Microscope means microscope spectrometers.

Forensic science of the future

What will forensic science look like in the future? Thanks to rapid technological advances, artificial intelligence has emerged in all fields of science, including investigation and forensic science.

Forensic science has a promising future, as new methods, technologies and scientific advances are creating opportunities that were previously undreamed of. The discovery and use of DNA has undoubtedly transformed current forensic science and will continue to do so, but as detection technologies evolve, we need to better understand the transfer of DNA trace, its persistence on a substrate, and its collection potential. New discoveries can bring about incremental or revolutionary changes (evolution or revolution) that together reshape the face of forensic science. We cannot predict what innovations and new technologies will emerge, but we can certainly expect them to materialise, and that AI will create new opportunities for forensic sciences.

Forensic science is often driven by specific problems and scandals, such as miscarriages of justice, and resources are devoted specifically to addressing them (Cole, 2016). This means that forensic science is often simply reactive to emerging 'symptoms' (Morgan, 2019; Morgan & Lewin, 2019), rather than a routine practice of ongoing and systematic proactive investigation, research and self-reflection.

Moreover, the fundamental paradigm of forensic science is that 'every case is different', which creates a deep-rooted tension between scientific research that seeks to develop generalisable theories and approaches and professional practices that aim to reconstruct the individual crime. Therefore, a longer-term review of the possibilities, potential and desirable outcomes is an important undertaking for the future of forensic science.

One of the fundamental challenges is that many areas of forensic investigation have developed within the practice of investigation (Garfinkel, 2010) rather than first being established through scientific research into its principles and foundations. This has resulted in many forensic disciplines having relatively small amounts of data (Gosch & Courtslow, 2019). One example is the issue of DNA transfer, i.e. the accidental transfer of material trace from one surface to another. (For this to become a real problem, recent technological advances have been needed. In the past, less sensitive methods were unaffected by the very small amount of DNA transferred.)

Looking ahead, one thing is almost certain: the future will see larger data sets, increased opportunities to use technological and laboratory information management systems, and the possibility of more transparent decision-making, transforming approaches based on anecdotal evidence (Dror et al., 2019).

The timescale is critical when it comes to vision, because the further into the future we look, the more unknown and unforeseen factors there will be. It is, however, predictable that forensic science in the future will take advantage of the development and exploitation of emerging technologies that will create new opportunities to capture, produce, store, search, synthesise, visualise and retrieve data.

It is also clear that with all these new and exciting opportunities come new challenges and vulnerabilities. Utopian fictions highlight the potential of this kind of data-rich world to transform society and human nature, but new technologies and capabilities also create a world that may face very serious challenges in terms of ethics, privacy, and certainly new challenges that are as yet unknown (Dror et al., 2019).

It is not possible to predict the specific details of the technological and scientific discoveries that will shape and advance forensic science in the future, but advances in technology and science will bring them. However, in order to recognise the potential of these new discoveries, it is useful to conduct thought experiments to develop a vision. Enhanced capabilities in data analysis evaluation and simulation that can address the complexity and dynamic nature of criminal reconstructions in individual cases can answer the deep and systemic challenges we face in crime reconstruction and the interpretation of evidence (Morgan, 2019; Morgan & Lewin, 2019).

Therefore, in this thought experiment, we envision a technology platform that will revolutionise the practice of forensic science. Such a platform offers the possibility to use existing forensic tools in new ways. It goes beyond database management: it also includes virtual reality and other immersive technologies to support investigators and courts (Gelder et al., 2019). It offers tools to ensure transparency on the variables taken into account and the decisions made, so that they can be checked later if necessary.

So the future looks bright. However, complex challenges require interdisciplinary, even holistic, solutions based on close cooperation between disciplines, and to achieve such capabilities, a truly interdisciplinary approach across the sciences, arts and social sciences is needed. Collaborating disciplines will combine efforts from computer science, statistics, cognitive sciences and other related fields to implement and exploit emerging technologies.

We must also ensure that we focus on both technological capabilities and the basic research that underpins evaluative interpretation (Morgan, 2019; Morgan & Lewin, 2019).

Systems for reconstructing the crime

When considering the future, it is important to consider how new capabilities arising from technological advances and the ability to capture and process data could transform forensic science, and how the digital revolution could change and influence it. Regardless of the specific details of the developments, it is foreseeable that future technologies will enable the creation of a platform that manages and integrates forensic activities into a simulator. This system can be called the *Integrative Reconstruction and Prediction Simulator* (IRPS). Such a unified platform allows the integration of findings from a very wide range of physical and digital materials, together with all relevant contextual information, to scientifically reconstruct a crime. And it does so in such a way that forensic science takes a truly holistic, integrative approach (Dror et al., 2019).

In this imaginary forensic science simulator, it will be possible to model different scenarios and outcomes (investigative hypotheses). Such tools are used in aviation and medicine. However, instead of the human body being the object of investigation – as in medical simulations – the IRPS will investigate the crime scene. Multiple simulations will be able to be run, using different forms of forensic evidence and incorporating the context of each piece of investigative data and evidence. In doing so, it will be possible to provide statistical probabilities for different scenarios, which can reconstruct what might have happened, by whom and when, and potentially contribute to crime prevention.

By running a multitude of possible reconstructions of crimes (based on available forensic evidence), this platform would allow the comparison of different scenarios, providing a differentiated diagnosis of the crime. The main question of course remains the well-known what happened, how it happened etc. A very similar approach to differential diagnosis is already being implemented in medicine. It is expected that IRPS will only be able to use information that is relevant to the task. Then, with the help of context management tools such as *Linear Sequential Unmasking* (LSU), IRPS can optimise the sequence of evidence examination and interpretation, ensuring that it is always the existing evidence that guides the crime reconstruction process, rather than a preconceived notion such as an 'ideal' targeted suspect (Dror et al., 2018).

In this futuristic vision of forensic science, such a tool will be able to take into account not only the analysis of the crime evidence individually, but also, if scientifically relevant, where it was found at the crime scene, what it was associated with, i.e. a whole range of relevant contextual information. For example, the location of latent fingerprints can be compared to the location and characteristics of splattered bloodstains, thus providing a relevant context for each other. With this in mind, IRPS can run various operations to simulate the likelihood of a variety of different actions or events, create reconstruction scenarios based on the evidence on the ground, using Bayesian and other statistical tools. In the future, an IRPS-like tool will have the potential to support inference not only at the source level, but also at the activity level (and even at the crime level) (Koeijer et al., 2019; Neumann et al., 2012). By running multiple simulations that consider different scenarios of 'by whom, when and what happened', it can distinguish, for example, between primary and secondary transmission of DNA traces, and provide information such as the profile of the most likely offender (Taylor et al., 2017).

However, if the forensic scientific evidence is insufficient or inconclusive, and too many possible scenarios can be imagined, subjective evidence such as witness testimonies can be used to further evaluate the different scenarios. This should be done in such a way that it is always transparent what investigative information and other evidence has been used to support each possible scenario. Such future capabilities will allow for forensic science to not only use IRPS to reconstruct and solve crimes, but also to better communicate and document the decision pathways leading to findings and to determine the weight of evidence provided to fact-finders. For example, it is conceivable that Virtual Reality (VR) approaches to IRPS could allow for a fully transparent presentation of different possible alternative crime reconstructions, their probabilities and causes, including possible uncertainties, limitations, biases and assumptions. Of course, the creation of such a capability would change the role of the police investigator, the use and support of technology, and how roles are shared between humans and machines (Dror & Mnookin, 2010). These will have far-reaching implications for the selection, training, experience and competencies of experts (Dror, 2013). The value of a forensic tool with this capability lies in its ability to generate and use large data sets through simulations of a variety of multivariate scenarios. In doing so, it can take into account the complex ecosystem of forensic science and therefore identify the potential root causes of specific challenges that may arise through the creation of existing and new technological capabilities. It will combine experimental data and expertise and provide tools to document each stage and decision so that cases can be re-evaluated in the future when new information or technologies become available. To ensure the integrity of the IRPS, it will be important to maintain its transparency, so it should be open source and freely available, and allow for the provision of an open forensic service (Chin et al., 2019) with full disclosure (Almazrouei et al., 2019).

Predictive policing

In such a futuristic vision of forensic science, IRPS-like tools will play a role in predicting crime. First, IRPS will be able to contribute to the prevention of existing crime types through analytical and evaluative work (Ribaux et al., 2014). For example, it does not evaluate crime scenes one by one, but creates a database of all crimes – past and present – which allows to identify the links between crimes, to identify patterns and to plan appropriate preventive policing measures.

Second, as society and technological capabilities change, new forensic tools will be needed to combat changing crime (Smolianitsky et al., 2014). For example, we are already seeing paper money being converted into polymer to leave fingerprints on the new plastic banknotes. As it becomes possible to capture, store, retain and search larger amounts of data, a system like IRPS can store and use a range of data, such as the chemicals used to make paint and ink, various tire marks, and digital signatures from various devices to improve data evaluation and interpretation. The IRPS may also be able to capture and use artificially modified elements in the production of certain goods, such as firearms, so that they can be easily traced and identified if used in a crime.

Third, future IRPS-like tools will have the additional capability to identify and predict new forms of crime enabled by emerging technologies. These could include the use of new digital capabilities, AI, machine learning, remote sensing, robotics, electronic remote controls for crime, or the new challenges that self-driving vehicles and drones will bring. These will inevitably and undoubtedly benefit society, but they will also offer criminals new criminal opportunities.

Through such predictive policing (Mátyás et al., 2020; Kisfonai, 2023; Herék, 2021) it will be possible to design systems that increase the chances of catching criminals, thus contributing to crime prevention (Clarke, 2004). AI-enabled forensics will not only focus on reconstruction and interpreting crime evidence from the crime scene but will also be able to create a more proactive 'think about crime' type of policing.

Concerns about AI-based predictive policing should also be mentioned, which is primarily a belief in the objectivity and infallibility of machine systems, complemented by a lack of transparency and accountability in AI system decisions (Leese, 2022). The need for accountability has led to the *AP4AI* project (Accountability Principles for Artificial Intelligence), which aims to promote transparency and accountability in the use of AI for homeland security worldwide (Akhgar et al, 2022). The modus operandi of an offender or group of offenders can also be extracted and organised from unstructured data sets, such as court judgments, police reports, etc, AI will also be needed to achieve true interoperability when it is necessary to quickly search and compare large numbers of name variants, face images, telephone numbers, etc.; think of an Arabic or Pashto name transcribed in Greek or Cyrillic letters, a Latin letter transcribed in

Hungarian pronunciation or English transcription, etc., and reviewing and comparing name variants would be a man-trying task when researching databases in several countries (Rahwan, 2022).

The future?

AI is rapidly becoming the most important applied science in all walks of life. Likewise, the forensic sector will benefit until our system becomes totally dependent on it. More and more people are recognising the importance of AI in their lives and are working to better understand it. Forensic science is the domain of professionals and AI will never reach that level, it will only serve as a complementary tool, we hope. Technology can facilitate expert work, but it will never be able to replace it.

Despite the overwhelming success of machine learning, the hardware that runs the system bears little resemblance to the human brain it imitates. The human brain weighs roughly a kilo and a half, and can tell you 'what, where, how many metres' with enough energy to power a light bulb. Today's AIs require weeks of training, several megawatt-hours of power and special processors to achieve anything approaching this level of detail.

In order to bring AI a little closer to the extreme size and energy efficiency of the human brain, 'neuromorphic' chips that mimic the structure of the brain are already being developed. Researchers at the Massachusetts Institute of Technology (MIT) have taken a step in this direction by producing an artificial synapse that can withstand strong electricity and thus outperform biological synapses in terms of speed. Electric fields in the brain are relatively weak, otherwise above 1.23 V the water in the cells would start to break down into hydrogen and oxygen. The speed of the human nervous system is therefore measured in milliseconds. The device developed at MIT operates at 10 volts with pulses of 5 nanoseconds, 10,000 times faster than its biological counterpart. However, its size is very small, a few nanometres - synapses in the human brain are thousands of times larger (Onen et al., 2022).

The tool currently faces several limitations. One is that the artificial synapse has three connectors: an output, an input and a regulator that determines the position of the proton, but this makes it difficult to build certain neural nets. Moreover, the incorporation of a hydrogen ion moving in the nanochannel makes mass production very difficult. The point is, however, that with further development, components can be produced that can easily be used to build hardware that matches or exceeds the capabilities of the human brain (Onen et al., 2022).

But let's hope that because the artificial brain is developed by the biological brain, it will never be like the human brain. Let's hope that machine learning in AI will eliminate cognitive bias but will never replace the role of the thinking human. What will happen to humanity if the singularity of AI occurs, i.e. the artificial mind is brought to the level of the human mind?

Raymond Kurzweil, renowned futurist, inventor and AI researcher, author of *The Threshold of the Singularity*, predicts the technological singularity will be reached by 2045. The date seems relatively close, but Kurzweil says this is due to the illusion of a linear pace of perceived progress, whereas real progress is exponential.

Summary

In our country, the authors have begun a thorough examination of the AI from a law enforcement or enforcement perspective. Csongor Herke's article (Herke, 2021) already cited in the context of predictive policing, describes the construction of offender profiles, social media profile analysis, recidivism risk estimation or facial image identification. The study by the authors Judit Dobó and Réka Gyaraki (Dobó & Gyaraki 2021) also focuses on the AI-based digitisation of facial recognition. István Fazekas presents first of all the danger of using AI as a weapon of the perpetrators (Fazekas, 2018), although he also mentions the ability of 'segregation', i.e. the fact that AI is particularly suitable for extracting the few relevant pieces of information from the sea of data. (Herke also presents the same in the context of the machine filtering of pornographic content about children.) Anna Zámpori touches on the possible role of AI in her paper on the digitisation of civil procedure (Zámpori, 2021), and András Czebe draws attention to the importance of the accessibility and transparency of algorithms in criminal law (Czebe, 2021).

Our two-part study aims to highlight the opportunities brought by AI infiltrating forensic science. In the natural sciences, the use of neural networks for data analysis and pattern recognition may be self-evident, but in forensic science we cannot forget that they are tools for fact-finding for law enforcement purposes. As such, they have legal, ethical and economic limitations and frameworks.

Nevertheless, the future is likely to be AI-assisted (but not triggered!) forensic expert work in fact-finding for law enforcement purposes. Thus, not only for forensic scientists, but also practicing forensic experts, and indeed law enforcement and all actors in the justice system, need to acquire some basic literacy in AI, machine learning and neural networks.

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