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Innovative potential of 3D technologies in crime investigation

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Abstract. The relevance of this study is conditioned by the need for constant updating of the specialised knowledge of criminalists and introduction of the latest technologies into the crime investigation. The purpose of this study was to critically examine the best practices of using 3D technologies in crime investigation. Through a systematic review of scientific studies that present various methods of using 3D technologies in crime investigation, it was proved that the scientific discourse is experiencing a revival of the discussion on the use of 3D technologies. Researchers note a series of benefits from the use of such technologies: 3D scanners allow creating a digital model of a crime scene; 3D reconstructions allow determining the sequence of actions, establishing cause and effect relationships, and restoring the original appearance of damaged objects; 3D printed models clearly demonstrate certain features of objects. The analysis of the available literature on the subject helped to systematise the use of 3D technologies in crime investigation and to identify three key areas of application of 3D technologies in the practice of crime investigation: (1) visualisation of the scene; (2) classification, identification, and diagnosis of objects; (3) reconstruction of objects or events. The speed, accuracy, safety, non-destructive impact, and many other criteria noted by researchers suggest that 3D innovations can become an indispensable auxiliary tool for criminalists, investigators, and prosecutors. At the same time, the findings of the analysed tests demonstrated certain limitations and problems that accompany the practice of using these innovations. As a result of the review of scientific literature, it was concluded that the transfer of 3D technologies in law enforcement is impossible without understanding the economic and social benefits of innovative investment. The study defined the content of these benefits, and the system of measures aimed at intensifying innovation processes in this area. The practical significance of this study is that its findings can be used by technical and forensic support units and pre-trial investigation bodies in developing the latest tactics for collecting evidence, recording, processing, and using information on criminal offences for the needs of criminal justice

Keywords: 3D innovations; virtual model; pre-trial investigation; evidence; crime scene; digital documentation

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Introduction

The study of the introduction of 3D technologies in the field of crime investigation is significant from a practical standpoint, since without innovative development, it is impossible to effectively address the task of combating crime and maintaining the rule of law. 3D technologies are developing rapidly and are confidently proving their advantages in various industries, including forensic science, which is the primary supplier of innovative products to the courtroom. A prerequisite for the development of a high-quality practice of applying 3D technologies is the availability of developed conceptual frameworks and methodologies for introducing innovations, which confirms the value of the present study in the theoretical context

L. Shymanovskaya-Dianych *et al.* (2021) proposed to understand the concept of "innovative potential" as "the ability to change, develop, improve, progress, it is a source of development... everything that leads to innovative development has innovative potential". Of professional interest is the study where V. Hnatkivskyi (2023) identified the forms of innovative investment. The proposed approach is suitable for expanding the capabilities of 3D technologies for collecting, evaluating, researching, and using evidence in criminal proceedings.

A. Haleem *et al.* (2022) detailed the principle of operation and types of 3D scanners, stages of application, data processing parameters, and the significance of innovation for industrial development. M. Javaid *et al.* (2021) made an analogous focus, describing sixteen areas of application of 3D technologies in the manufacturing sector. These studies confirm two facts: firstly, the trend of 3D innovations is undeniable and it is scaling in multiple directions; secondly, human activity under the influence of this trend is changing substantially, improving its quality and speed, but changing the configuration of jobs and the requirements for the competence of specialists.

R.H. Home *et al.* (2024) substantiated the outstanding potential of 3D technologies for Bloodstain Pattern Analysis (BPA) and presenting such evidence in court and concluded that innovations are useful not only from the standpoint of technical value but also for ethical reasons, since such evidence does not have the traumatic emotional impact on judges and jurors that real photos from the scene would have. S. Mânica *et al.* (2024) and B. Beltrame *et al.* (2024) confirmed the suitability of 3D technologies for identifying people by teeth and teeth marks (bites). J. Pérez *et al.* (2024) proposed a methodology for cost-effective tools that could be used by any police team to efficiently capture, measure, process, and generate 3D models of the environment and 3D reconstructions of road traffic accidents. These and many other studies give an idea of the relevance of the needs of pre-trial investigation, expert research, and the broad prospects for the introduction of 3D innovations.

There are no specialised monographs or dissertations in Ukrainian science that would cover the issue of transferring 3D technologies to the sphere of criminal proceedings. Y.P. Poliak (2022) confirmed that the national scientific doctrine of criminal procedure and forensics does not have any thorough research on the specific features of the use of technical means during investigative actions and the use of their findings during pre-trial investigation. At the same time, Y.P. Poliak only briefly mentioned 3D models, 3D scanning, and 3D printing technologies, presenting them rather to illustrate certain theoretical hypotheses than to provide a thorough discourse on the methodology, advantages, and problems of application. There are also few professional publications in Ukrainian periodicals in this area. An exception may be the publication where R.I. Blahuta *et al.* (2020) focused on highlighting the benefits of using 3D scanning in criminal proceedings, but did not explore in detail the issues of 3D reconstructions or 3D printing, nor did it present the risks and challenges that may arise in connection with the testing of the latest tools in crime scene investigations. The above calls for a comprehensive analysis of the innovative potential of 3D technologies for a specific area of investigation. This is viewed as a response to the ever-growing need in modern conditions to meet the social demand for public safety, effective crime prevention, and fair justice.

The purpose of this study was to form the basis for a decision on the significance of attracting investments in the development of 3D technologies in the field of criminal proceedings, which will contribute to the performance of crime prevention tasks and, as a result, strengthen public security and legal order. To fulfil this purpose, it was necessary to implement the following tasks: firstly, to investigate the significance and determine the primary areas of application of 3D technology in the practice of crime investigation; secondly, to find the economic and social benefits of investing in the transfer of 3D technology in the practice of crime investigation.

These objectives were achieved through a systematic review of the scientific literature on the subject. This helped to consider various aspects of the use of 3D technologies in crime investigation, including methods, tools, technical characteristics, and areas of application. The systematic analysis helped to identify key findings and prioritise research areas. By synthesising the results of various studies, a comprehensive view of the potential of 3D technologies in crime investigation was obtained. A comparative analysis of the literature helped to understand which methods are most effective in concrete situations and how to optimise their use. Summarising the findings of the study and practices of using 3D technologies in crime investigation helped to identify general principles and strategies that may be useful for the further development of this field. Using these methods, three blocks of research on the subject were analysed. The first block included publications relevant to the concept of "innovation potential" in science in general and forensics specifically. The second block included sources that present the basics of functioning and prospects for the introduction of 3D technologies in the global economy, industrial production, construction, medicine, etc. The third block was the most numerous. It included studies that focused on various aspects of the introduction of 3D technologies directly into law enforcement.

Significance and primary areas of application of 3D technologies in the practice of investigating crimes

The analytical documents on global trends until 2030 (Gaub, 2019) and 2040 (Global Trends 2040..., 2021) note that understanding the nature of modern transformations and strategic forecasting of future changes in the geopolitical, geo-economic, and geotechnological order give grounds for a reasonable conclusion that in the coming decades, 3D technologies will continue to be in prominent positions in the ranking of global innovations due to their potential to transform various spheres of life, increase productivity, and

integrate the achievements of other sciences. This proves that the intensification of investment processes in this area is economically feasible and strategically expedient.

3D technologies are actively gaining key positions in many areas of human activity. Industrial production, art history and archaeology, plastic surgery, dental and orthopaedic medicine, architecture, engineering and construction, the film industry, animation, and video game creators all use 3D scanners. The technologies allow for reverse engineering of parts, which enables fast and accurate production of products, such as a prosthetic limb of such quality that will provide maximum comfort, movement, and pain relief for the patient. Automation of quality control during production and the need for increased productivity through the use of electronics are considered key reasons for the growth of this market (Haleem *et al.*, 2022).

The essence of 3D technologies is based on the creation of a cloud of points of a scanned physical object, each of which has three-dimensional coordinates (x, y, z). As a result, the physical object is recreated as a virtual model of a concrete object or virtual reality representing the situation in an open area or indoors. The resulting three-dimensional objects can be investigated using additional data processing tools (measurements, reconstruction, study of the characteristics of certain objects, their relative position, etc.) or a copy can be printed using a 3D printer. In the context of this study, the concept of "3D technology" was applied as a generalisation to various activities based on the principle of creating a three-dimensional virtual model of an object and various forms of data processing: 3D scanning, 3D reconstruction, 3D cartography, 3D animation, 3D modelling, 3D printing, etc.

Naturally, such broad innovative capabilities have aroused professional interest among practitioners involved in crime prevention and criminal investigation. A series of applied studies have emerged that prove the advantages of using 3D technologies in documenting crimes compared to traditional methods of recording information. Such conventional methods include verbal description in the investigative report, photography and video recording, drafting a diagram, and sometimes making plaster or silicone casts and copies. The advantages of 3D innovations include scanning speed, data reproduction accuracy, portability of tools, saving procedural resources due to the absence of the need for detailed verbal descriptions of the crime scene environment, as well as the removal of certain restrictions (e.g., vehicle movement due to the recording of a traffic accident), safety of use, multifunctionality of technologies, and the possibility of combining them with achievements in other fields of science and technology (Blahuta *et al.*, 2020; Vargas *et al.*, 2021; Haleem *et al.*, 2022)

The innovative potential and practical significance of 3D technologies in crime investigation is evidenced by field studies. Polish scientists M. Adamczyk *et al.* (2017) tested the methodology of scanning real crime scenes after the information had been recorded in the conventional way. In three of the seven cases, the documentation of 3D technology specialists was attached to the criminal proceedings, which confirmed the high quality of the work performed. Danish experts C. Villa *et al.* (2024) and Italian forensic scientists M. Esposito *et al.* (2023) have already gained many years of experience in adapting 3D technologies to the needs of crime investigation. D. Errickson *et al.* (2022) provided numerous cases of the use of 3D printing in the criminal justice system in England and Wales. The positive experience of using 3D technologies in the courtroom was presented by American scientists (3D Laser Scanning..., n.d.). Based on the generalisation of scientific literature, three primary areas of application of 3D technologies in criminal proceedings can be distinguished: visualisation of the scene of an event; classification, identification, and diagnosis of objects; reconstruction of objects or events.

In many cases, especially when it comes to grave crimes (murder, fire, terrorist attack, plane crash, road traffic accident with many victims, violations of international humanitarian law, such as significant destruction of civilian infrastructure as a result of rocket or artillery fire, etc.), it is of utmost significance to record the situation quickly, fully, and accurately. Inspection of the scene is an urgent procedural action that determines the success of the subsequent investigation and collection of evidence. The presence of a massive number of traces, significant destruction or damage results in a considerable amount of time and resources spent on recording them using conventional methods. Their use is undoubtedly important, but no description in the report or photograph allows investigators, prosecutors, witnesses, or judges to "return to the scene" after a certain amount of time has passed. However, the 3D scanner provides a digital product that will reproduce the details of the scene with great accuracy, providing the ability not only to move into this virtual, dynamic, safe, and controlled environment, but also to perform certain analytical operations and research. The technology provides free navigation and 360-degree movement in the point cloud of the scanned scene, segmentation of various parts of the cloud, extraction of parts of the point cloud, their translation into 2D, improvement of the point cloud visualisation by increasing or decreasing the density of points, colour correction, etc. Additionally, 3D technologies can revolutionise the way information about the crime and its participants, data on traces found, information about means and tools, etc., is presented in court.

The second area relates to the ability to classify objects, solve diagnostic problems, and establish individual identities of objects that would otherwise be unsuitable for research or require excessive efforts to identify identifying features of objects. This includes, for instance, the ability to scan footprints or vehicle tracks on a loose surface (sand, specific dry soil). No high-quality forensic photograph can produce an image like the 3D scanner's visualisation. Likewise, a static plaster or silicone cast will not provide correct information, if at all, if it is possible to make it on a fragile base. However, the non-destructive and non-contact method of applying 3D technologies provides not only high-quality capture of the characteristic pattern of the detected object (trace), but also the possibility of reverse engineering. This enables the creation of a three-dimensional "reverse" model that can serve as an effective auxiliary tool for further solving identification, classification, and diagnostic tasks (Colwill, 2016; Bennett & Budka, 2018). An analogous technology is used to identify bite marks on the human body and study bodily injuries (characteristics of wounds, abrasions, etc.) (Beltrame *et al.*, 2024). A. Brough *et al.* (2019) emphasised the benefits of medical imaging and 3D modelling in forensic anthropology, stressing that in the current context, forensic anthropologists can use these technologies in every aspect of their forensic research: from documenting the scene to analysing the smallest bone fragment.

While the previous two areas were mainly concerned with the recording and study of objects in different projections, virtual reconstruction involves the construction of a moving model that represents the dynamics of change and the cause-and-effect relationships of an event. Based on the entered data, situational tasks are solved in the form of computer animations. This approach can be used to investigate the sequence of actions, such as the movement of vehicles in a car accident, or to study the mechanism of blood traces (patterns) on a wall (BPA) or to establish the trajectory of a bullet (Griffiths *et al.*, 2021; Stevenson & Liscio, 2024). Such information can be used by investigators and prosecutors to confirm or refute versions; to verify the testimony of witnesses, victims, suspects, and accused; to plan further procedural steps in the investigation algorithm.

Another method of reconstruction refers to the restoration by modelling the appearance of an object (e.g., post-mortem reconstruction of the face of an unidentified corpse with a head injury, mutilated facial soft tissue) or a material representation of a particular object resulting from the production of a polymeric copy (e.g., a crime weapon, fragments of a broken bone, etc.) by 3D printing (Vargas *et al.*, 2021; Jakobsen *et al.*, 2023). Firstly, such reconstruction can serve as a valuable tool for identification through the distribution of relevant orientation, checking against records, and presentation for identification. Secondly, printed polymer analogues of means, tools, bones, etc., can be delivered to the courtroom and contribute to a more realistic perception of the circumstances of the event by interested parties to criminal proceedings, as well as a better understanding of the conclusions of forensic experts.

At the same time, when assessing the prospects for widespread adoption of innovations, one cannot ignore the issue of shortcomings and limitations that have been identified and are currently being studied by experts. B.F. Vargas *et al.* (2021), A. Haleem *et al.* (2022), S. Kottner *et al.* (2023) identified the following as the "weaknesses" of 3D technologies:

- some parts of the scanned objects may be falsely reflected due to the presence of shiny surfaces, polished materials, or very dark surfaces that distort the signal to the scanner;
- transparent surfaces (e.g., glass) can also be problematic for technical processing, as the scanner scans through glass without distinguishing it in a given environment;
- the need for direct visibility of objects due to the optical nature of the scanning technology;
- substantial difficulties with details of small objects with complex geometry, as well as with details placed on a specific background (e.g., grass) due to the effect of "information noise";
- climate conditions (temperature, humidity) and lighting substantially affect scan quality;
- polymer copies printed using 3D printing technologies may be fragile, have varying degrees of grooves and other features that are accompanying components of the technological process and may render further identification impossible;
- a mandatory component of 3D technologies is special software, the use of which by various entities (investigator, expert, prosecutor) may lead to compatibility issues, as well as mandatory periodic calibration of all devices.

Economic and social benefits of investing in 3D technology transfer in crime investigation practice. The conventional process of documenting information at the scene of an incident is usually complex and time-consuming. However, the attractive features of the 3D documentation technology are not at all attractive, which may be an obstacle to the introduction of the innovation on a large scale. G. Vidoli *et al.* (2020) presented valuable research findings. The researchers conducted a survey to analyse the cost-effectiveness of different methods of recording information about a crime. The study involved 461 respondents, including both forensic experts and laypeople. The study found that hand-drawn maps are the most affordable means of capturing crime information, with an average cost of USD 0.79 per minute, but only 2.4% of respondents chose this method as the best method of capturing forensic information. Two-dimensional topographical diagrams had an average accuracy of over 70% and cost approximately USD 300 per minute to produce, but only 3.1% of respondents preferred this method. Photography was half the price (at a cost of USD 126 per minute), but only 23.4% of respondents reported that it was their preferred method. Finally, 67.8% of respondents named 3D scanning as the best method of documenting information about a criminal event, but the cost per minute of using this technology exceeds USD 800 (Vidoli *et al.*, 2020). Ground-based scanners cost between USD 20,000 and USD 70,000, which is a high price for typical law enforcement budgets. Hand-held scanners are lower priced (cost range of USD 5,000 to USD 18,000), but this amount is still too high for many CSI units (Tredinnick *et al.*, 2019).

Therefore, to achieve productive results, investment is required, which can be implemented in various forms: (1) investment under individual investment agreements (contracts); (2) grant investment at the expense of resources, assets, innovations, funds of international organisations, intergovernmental organisations, international institutions, state authorities, or local self-government; (3) crowdfunding; (4) investment through the creation of joint ventures; (5) public procurement; (6) investment within the activities of specialised infrastructure entities of the innovation system (technopolises, technoparks, science parks, business incubators, etc.) (Hnatkivskyi, 2023).

In a comparable study of the cost-effectiveness of 3D scanning technology in crime scene investigation, R. Tredinnick *et al.* (2019) considered the following indicators in the cost-benefit analysis algorithm:

- purchase of new or upgrade of computers powerful enough to process and visualise scanned data;
- upgrading of the server infrastructure for storing and backing up scan data, which forms a large file repository;
- fixed costs, such as software licensing fees;
- environmental limitations, such as the inability of some 3D scanners to work outdoors in very bright sunlight or in bad weather;
- expenditures on training employees in the use of technology and data.

In a situation where a small number of crimes are committed in the service area of a particular unit that has spent money on 3D scanning equipment, the benefits of saving time at the scene, restoring traffic due to road accidents, etc., are negligible. However, in a scenario where the equipment is used frequently, innovative investments are economically substantiated. An illustrative example is the fluctuation of net benefits from USD 13,809 in Montana, where the use of 3D scanners was infrequent, to USD 799,541 in California, where the use of 3D scanners was systematic (Tredinnick *et al.*, 2019).

The social benefit of using such innovations is to build public confidence that information about a crime will be documented quickly, fully, and efficiently, and that this process will have a logical conclusion in the form of holding the perpetrators responsible and restoring justice. The use of innovations creates a positive image for law enforcement agencies, especially when it comes to technologies that are used, as it were, "in front of the public" at the scene of a crime. This is a sign that the criminal procedure system is adapting to the latest trends and updating its methods and forms of work in the context of technological advancement.

The prospects for the development of digital documentation are viewed in the gradual reduction in the cost of these technologies. The rapid movement in this area is evidenced by a study that demonstrated that in an artificially simulated crime situation, even a mobile phone with a special application programme can be used to scan a garage or parked car within a few minutes without special preparation. S. Kottner *et al.* (2023) tested the Recon-3D application based on typical crime scenarios and confirmed that a mobile device such as a smartphone or tablet can be used as an optical 3D scanner with the addition of a LiDAR sensor to digitally document the scene. The resulting spatial information has a sufficiently high resolution, although this depends on the distance to the objects, increases the amount of data and lengthens the time for the software to process the information (Kottner *et al.*, 2023). S. Stevenson and E. Liscio (2024) obtained analogous findings on the rather high efficiency of iPhone LiDAR and Recon-3D in the study of the mechanism of blood traces formation. The scientists stated that, compared to more complex ground-based laser scanning systems, such portable devices allow obtaining sufficiently accurate results of scanning stains and other traces of blood at the scene. The error varies at the level of 3 mm. Maiese *et al.* (2022) also confirmed the suitability of portable tools for virtual autopsies.The second significant aspect of further development of innovations is their combination with other technologies, such as drones and 3D technologies, which allows for aerial surveys and mapping (Galvin, 2020; Addo & Jayson-Quashigah 2021; Lee *et al.*, 2024). The combination of computed tomography and 3D technologies allows creating a virtual 3D animation of the entire body and visualising damage to internal organs or the skeleton (Maiese *et al.*, 2022; Gupta, 2023; Villa *et al.*, 2024). Scientists are discussing the possibilities of combining 3D scanning and virtual reality (VR), including the prospects of creating repositories of 3D digitised crime scenes. These resources will be available to specialists who, within the framework of their cooperation and assistance during the investigation, will be able to conduct online research on virtual 3D reconstructions (Rinaldi *et al.*, 2022)

The conducted systematic literature review convincingly proves that attention to the innovative potential of 3D technology will only increase in the near future. According to G. Baldino *et al.* (2023), this refers to a doorway to the future virtual reality and innovative "metaverse". This global trend has already proved its effectiveness and usefulness in many areas of human activity, which substantially influences the economic potential and employment. At the same time, the capabilities of 3D technologies are being tested with great caution in the field of crime prevention. Recently, there has been an intensification of discussions on the use of 3D scanners during crime scene inspection to create a virtual picture of the crime scene, 3D reconstructions during research and examination to determine the sequence of actions, establish cause and effect relationships, etc., and printed 3D models to demonstrate certain features of objects relevant to the investigation. Table 1 summarises the key areas of application of 3D technologies in crime investigation.

Table 1. Areas of application of 3D technologies in crime investigation

Scope	Potential applications 3D technologies	Examples of research
Visualisation of the scene	Creation of digital models of the scene of an incident for the purpose of ensuring: ➨ recording and visualisation of the crime scene; ➨ creation of an interactive environment where objects are available for viewing and studying in different projections; ➨ transferring judges, lawyers, prosecutors, jurors, and other participants in criminal proceedings to the virtual environment of a crime scene.	V. Rinaldi *et al.* (2022); A. Ospina-Bohórquez *et al.* (2023); S. Kottner *et al.* (2023).
Classification, identification, and diagnostics	Study of object features for further identification, classification, and diagnosis: ➨ examination of teeth marks (bite marks) and other bodily injuries; ➨ examination of shoe sole marks; ➨ investigation of vehicle tracks (traces); ➨ investigation of tool marks.	R. Bennett and M. Budka (2018); B. Vargas *et al.* (2021); C. C. Villa *et al.* (2024).
Reconstruction of facilities and/or events	Visual reconstruction For example, the reconstruction of facial fragments of a mutilated unidentified corpse.	R.M. Carew *et al.* (2021); B.F. Vargas *et al.* (2021); S.R. Jakobsen *et al.* (2023).
	Material reconstruction For example, 3D printing of bones and weapons.	
	Situational reconstruction For example, modelling of: ➨ the mechanism of road traffic accidents; ➨ the mechanism of blood traces (BPA); ➨ the mechanism of gunshot injuries.	

Source: compiled by the authors of this study

The forecast for the further development of 3D technologies is so optimistic that it gives grounds to discuss the emergence of a new field – "3D Forensic Science" (3DFS), which combines approaches and methods, investigating the experience and best practices of using 3D technologies for the needs of criminal justice (Carew *et al.*, 2021). The combination of conventional methods of capturing information (photography, video recording, verbal description) and 3D information processing methods opens new opportunities for working with evidence, modelling the mechanism of a crime, and presenting essential information in court. The speed, accuracy, safety, non-destructive effect, multifunctionality, and many other criteria suggest that 3D innovations can become a valuable addition to the work of criminalists, forensic scientists, investigators, and prosecutors.

There are two scenarios to consider: (1) the outcomes of implementing 3D technology; (2) the consequences of not implementing the technology. Under the first scenario, one can expect to see a strengthening of positions in digital documentation of illegal activities; improvement of the quality of collecting relevant information about the crime and criminals; and increased efficiency in the courtroom when presenting evidence to judges and jurors. At the same time, it is likely to increase the workload of law enforcement officers, who, along with conventional methods, will be required to use 3D innovations; it will not always be possible to guarantee a high-quality result, as the technological process of 3D scanning, 3D reconstruction, or 3D printing has certain conditions and limitations; it will be necessary to agree to reallocate financial resources in such a way as to provide the relevant units with equipment and software, which will likely result in a reduction in investment in other innovative programmes (b). In the first scenario, if it were to be remarkably successful, there would likely be a transformation of jobs, with some staff being laid off, but new jobs being created for specialists ready to work with these technologies (Gaub, 2019).

In the second scenario, conventional methods of recording and investigating information about crimes and methods of collecting evidence will continue to be used, but there will be a risk of technological lagging behind criminals themselves, who are increasingly using the innovative potential of technology as a resource to fulfil their criminal intentions (e.g., using 3D printing to make disposable tools of crime, such as bullet shooters or lock pickers (de Almeida, 2020; Daly *et al.*, 2021; Listek, 2023). In such circumstances, a criminal justice system that is unable to adapt to the new conditions of operation will be unable to perform its core functions.

Thus, it is vital to intensify innovation processes and introduce incentives for innovative investment. G. Jani *et al.* (2021) rightly pointed out the need to develop standardised working protocols for the 3D scanning process, setting 3D modelling parameters for printing (layer height, temperature, speed), post-processing procedures to create accurate copies of evidence, and defining legal and ethical principles for their use. Analogously, D. Errickson *et al.* (2022) are convinced that to make tangible progress in the integration of 3D technologies into the criminal justice system, it is crucial that academics and practitioners are united by the shared goal of developing national guidelines. Additionally, it is necessary to create favourable conditions for scientific collaboration in clusters that include both scientists and practitioners-stakeholders (target audience) to conduct further research; optimise international mobility of researchers and practitioners; develop universal methods of work in different situations of crime, in different types of crime scenes; invest in infrastructure (special equipment, software, maintenance, and repair) and specialised training of personnel; study the best foreign practices of using and new achievements of 3D technologies.

Considering the specifics of the use of the latest technologies, extensive financial resources and a certain amount of time to master special skills in working with equipment and software, it appears advisable to implement a pilot project – the creation of a separate Special Innovation Support Unit (SISU) at the regional headquarters of the National Police. The specialists of this unit could be involved in preparing addenda to the protocols of procedural actions using 3D scanners, drones, and other modern equipment. The task of providing special training and relevant equipment for each regional centre is more realistic in the short term than making such technologies available to each territorial police unit. According to O. Dufeniuk (2023), the activities of SISUs should be regulated by separate regulations, for instance, by analogy with the regulation of forensic laboratories. This will require supplementing Decree of the Ministry of Internal Affairs of Ukraine No. 1339 (2015) with a separate section III-I of the Instruction on the procedure for engaging employees of pre-trial investigation bodies of the police and the Expert Service of the Ministry of Internal Affairs of Ukraine as specialists to take part in the examination of the scene.

Conclusions

Considering the spread of the general global trend of digitalisation and development of 3D technologies, the issue of using their innovative potential in criminal proceedings to perform the tasks of combating crime and strengthening public security is of considerable interest. Based on a systematic thematic analysis of scientific sources, periodicals in the field of innovative technologies and forensic science, the study identified numerous scientific and applied studies which reasonably prove the expediency of expanding the practice of using 3D technologies in law enforcement activities. The findings of the study became the basis for differentiating three primary areas of application of 3D technology in the practice of crime investigation: visualisation of the scene; classification, identification, and diagnostics of objects; reconstruction of objects or events.

At the same time, attention was drawn to the identified risks and "weaknesses" of 3D technologies, such as the falsity of certain reflections, difficulties with intricate details, or climatic limitations. The transfer of 3D technologies to law enforcement is impossible without understanding the economic and social benefits of innovative investment. The findings of this study provided grounds for in-depth reflection on the feasibility of introducing 3D technologies in small towns, as there is less probability of their use and, therefore, the net benefit will be lower compared to such an investment in a large city, which has a larger population, a greater number of crimes committed, a greater need to document events and collect evidence, and, therefore, the net benefit will increase substantially. Social benefit is difficult to monetise, to express in economic terms. This refers to building public confidence in the criminal justice system, confidence that information about a crime will be documented quickly,

fully, and efficiently, and that this process will have a logical conclusion in the form of bringing the perpetrators to justice through due process.

The proposed study presented a view of two scenarios (when 3D technologies are introduced and when they are not) and identified a set of measures aimed at intensifying innovation processes in this area. Their clear understanding and broad discussion on various discussion platforms is an essential prerequisite for the successful implementation of the state's innovation policy and technology transfer in the criminal justice sector, the ultimate beneficiary of which is society. Promising areas for further research include the systematic development of the foundations of three-dimensional forensics as a unique branch of scientific knowledge, the subject of which is theoretical provisions and practical recommendations on the use of 3D technologies for the collection (detection, recording, seizure, storage), research, evaluation, and use of evidence in criminal proceedings.

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Conflict of interest

The authors of this study declare no conflict of interest.

References

[1] 3D Laser Scanning: Positioning the Jury at the Scene of a Murder. (n.d.) Retrieved from https://media.faro.com/-/media/Project/FARO/FARO/FARO/Resources/2021/01/15/22/31/Case-Study-3D-Laser-Scanner-positions-jury-at-the-scene-of-a-murder-ENG.pdf?rev=4a9e73d03cea43feaf6536a659d38227.

[2] Adamczyk, M., Hołowko, E., Lech, K., Michoński, J., Mączkowski, G., Bolewicki, P., Januszkiewicz, K., & Sitnik, R. (2017). Three-dimensional measurement system for crime scene documentation. *Counterterrorism, Crime Fighting, Forensics, and Surveillance Technologies*, 10441, article number 104410A. doi: 10.1117/12.2278489.

[3] Addo, K.A., & Jayson-Quashigah, P.N. (2021). UAV photogrammetry and 3D reconstruction: Application in coastal monitoring. In *Unmanned aerial systems: Theoretical foundation and applications* (pp. 157-174). Cambridge: Academic Press. doi: 10.1016/B978-0-12-820276-0.00014-5.

[4] Baldino, G., Spagnolo, E.V., Fodale, V., Pennisi, C., Mondello, C., Altadonna, A., Raffaele, M., Salmeri, F., Somma, R., Asmundo, A., & Sapienza, D. (2023). The application of 3D virtual models in the judicial inspection of indoor and outdoor crime scenes. *Proceedings of the Accademia Peloritana dei Pericolanti-Class of Physical, Mathematical and Natural Sciences*, 101(1), article number 17. doi: 10.1478/AAPP.101S1A17.

[5] Beltrame, B., Fassina, G., Aprile, A., & Verzeletti, A. (2024). Bitemarks and 3D scanner: An objective comparison for bitemarks. A pilot study. *Journal of Forensic and Legal Medicine*, 102, article number 102639. doi: 10.1016/j.jflm.2024.102639.

[6] Bennett, M.R., & Budka, M. (2018). *Digital technology for forensic footwear analysis and vertebrate ichnology*. Germany: Springer International Publishing. doi: 10.1007/978-3-319-93689-5.

[7] Blahuta, R.I., Blikhar, V.S., & Dufeniuk, O.M. (2020). Transfer of 3D scanning technologies into the field of criminal proceedings. *Scientific Innovation*, 16(3), 88-95. doi: 10.15407/scine16.03.084.

[8] Brough, A., Rutty, G., Villa, C., Colman, K., Dedouit, F., & Decker, S.J. (2019). The benefits of medical imaging and 3D modelling to the field of forensic anthropology positional statement of the members of the forensic anthropology working group of the International Society of Forensic Radiology and Imaging. *Journal of Forensic Radiology and Imaging*, 18(4), 18-19. doi: 10.1016/j.jofri.2019.07.003.

[9] Carew, R.M., French, J., & Morgan, R.M. (2021). 3D forensic science: A new field integrating 3D imaging and 3D printing in crime reconstruction. *Forensic Science International: Synergy*, 3, article 100205. doi: 10.1016/j.fsisyn.2021.100205.

[10] Colwill, S. (2016). *Low-cost crime scene mapping: Reviewing emerging freeware, low-cost methods of 3D mapping and applying them to crime scene investigation and forensic evidence*. Perth: Murdoch University.

[11] Daly, A., Mann, M., Squires, P., & Walters, R. (2021). 3D printing, policing and crime. *Policing and Society*, 31(1), 37-51. doi: 10.1080/10439463.2020.1730835.

[12] de Almeida, F.E.G. (2020). 3D printing and new security threats. *Revista do Instituto Brasileiro de Segurança Pública*, 3(7), 197-210. doi: 10.36776/ribsp.v3i7.92.

[13] Decree of the Ministry of Internal Affairs of Ukraine No. 1339 "On Approval of the Instruction on the Procedure for Involvement of Employees of Pre-trial Investigation Bodies of the Police and the Expert Service of the Ministry of Internal Affairs of Ukraine as Specialists to Participate in the Examination of the Scene of the Incident". (2015, November). Retrieved from https://zakon.rada.gov.ua/laws/show/z1392-15#Text.

[14] Dufeniuk, O.M. (2023). *Conceptual model of balance in criminal proceedings: Institutional, law application, personal levels*. (Doctoral thesis, Lviv State University of Internal Affairs, Lviv, Ukraine).

[15] Errickson, D., Carew, R.M., Collings, A.J., Biggs, M.J.P., Haig, P., O'Hora, H., Marsh, N., & Roberts, J. (2022). A survey of case studies on the use of forensic three-dimensional printing in England and Wales. *International Journal of Legal Medicine*, 136(6), 1605-1619. doi: 10.1007/s00414-022-02872-4.

[16] Esposito, M., Sessa, F., Cocimano, G., Zuccarello, P., Roccuzzo, S., & Salerno, M. (2023). Advances in technologies in crime scene investigation. *Diagnostics*, 13(20), article number 3169. doi: 10.3390/diagnostics13203169.

[17] Galvin, R. (2020). *Crime scene documentation: Preserving the evidence and the growing role of 3D laser scanning*. London: Taylor & Francis.

[18] Gaub, F. (2019). *Global Trends to 2030*. Retrieved from https://ec.europa.eu/assets/epsc/pages/espas/ESPAS Report2019.pdf.

[19] Global trends 2040: A more contested world. (2021). Retrieved from https://www.dni.gov/files/ODNI/documents/assessments/GlobalTrends 2040.pdf.

[20] Griffiths, G., Liscio, E., Guryn, H., Le, Q., Northfield, D., & Williams, G.A. (2021). Inter-observer error for area of origin analysis using FARO Zone 3D. *Science & Justice*, 61(3), 291-298. doi: 10.1016/j.scijus.2021.02.006.

[21] Gupta, S.K. (2023). *Forensic pathoradiology of virtual autopsy*. Boca Raton: CRC Press. doi: 10.1201/9781003383703.
[22] Haleem, A., Javaid, M., Singh, R.P., Rab, S., Suman, R., Kumar, L., & Khan, I.H. (2022). Exploring the potential of 3D scanning in Industry 4.0: An overview. *International Journal of Cognitive Computing in Engineering*, 3, 161-171. doi: 10.1016/j.ijcce.2022.08.003.
[23] Hnatkivskyi, B. (2023). Justification of directions for improving state regulation of innovative investment. *Eastern-European Journal of Enterprise Technologies*, 6(13), 65-73. doi: 10.15587/1729-4061.2023.294761.
[24] Home, P.H., Norman, D.G., Wade, K., Spearing, E., & Williams, M.A. (2024). 3D scanning a crime scene to enhance juror understanding of Bloodstain Pattern Analysis evidence. *Science & Justice*, 64(3), 333-338. doi: 10.1016/j.scijus.2024.04.007.
[25] Jakobsen, S.R., Pedersen, C.C., Thomsen, A.H., & Hansen, K. (2023). 3D-print as a template for reassembly of skull fragments in a homicide case. *Annals of 3D Printed Medicine*, 12, article number 100137. doi: 10.1016/j.stlm.2023.100137.
[26] Jani, G., Johnson, A., Marques, J., & Franco, A. (2021). Three-dimensional (3D) printing in forensic science – an emerging technology in India. *Annals of 3D Printed Medicine*, 1, article number 100006. doi: 10.1016/j.stlm.2021.100006.
[27] Javaid, M., Haleem, A., Singh, R.P., & Suman, R. (2021). Industrial perspectives of 3D scanning: Features, roles and it's analytical applications. *Sensors International*, 2, article number 100114. doi: 10.1016/j.sintl.2021.100114.
[28] Kottner, S., Thali, M.J., & Gascho, D. (2023). Using the iPhone's LiDAR technology to capture 3D forensic data at crime and crash scenes. *Forensic Imaging,* 32, article number 200535. doi: 10.1016/j.fri.2023.200535.
[29] Lee, E., Park, S., Jang, H., Choi, W., & Sohn, H.G. (2024). Enhancement of low-cost UAV-based photogrammetric point cloud using MMS point cloud and oblique images for 3D urban reconstruction. *Measurement*, 226, article number 114158. doi: 10.1016/j.measurement.2024.114158.
[30] Listek, V. (2023). *3D printed guns in Europe: Recent developments, legal complexities, and insights from an expert.* Retrieved from https://3dprint.com/304988/3d-printed-guns-in-europe-recent-developments-legal-complexities-and-insights-from-an-expert/.
[31] Maiese, A., Manetti, A.C., Ciallella, C., & Fineschi, V. (2022). The introduction of a new diagnostic tool in forensic pathology: LiDAR sensor for 3D autopsy documentation. *Biosensors*, 12(2), 132. doi: 10.3390/bios12020132.
[32] Mânica, S., Boedi, R.M., Pandey, H., & Shields, C. (2024). Identifying teeth and tooth fragments from digital 3D models. *Morphologie*, 108(362), article number 100774. doi: 10.1016/j.morpho.2024.100774.
[33] Ospina-Bohórquez, A., Del Pozo, S., Courtenay, L.A., & González-Aguilera, D. (2023). Handheld stereo photogrammetry applied to crime scene analysis. *Measurement*, 216, article number 112861. doi: 10.1016/j.measurement.2023.112861.
[34] Pérez, J.A., Gonçalves, G.R., Barragan, J.R.M., Ortega, P.F., & Palomo, A.A.M.C. (2024). Low-cost tools for virtual reconstruction of traffic accident scenarios. *Heliyon*, 10(9), article number e29709. doi: 10.1016/j.heliyon.2024.e29709.
[35] Poliak, Y.P. (2022). *The use of technical means in conducting investigative (search), covert investigative (search) actions and the use of its results during the pre-trial investigation.* (PhD thesis, Lviv State University of Internal Affairs, Lviv, Ukraine).
[36] Rinaldi, V., Hackman, L., & NicDaeid, N. (2022). Virtual reality as a collaborative tool for digitalised crime scene examination. In *International conference on extended reality* (pp. 154-161). Cham: Springer International Publishing. doi: 10.1007/978-3-031-15546-8_14.
[37] Shymanovskaya-Dianych, L., Chernikova, N., & Ishcheikin, T. (2021). The essence of the concept of "innovation potential" as an economic category. *Business Navigator*, 3(64), 63-69. doi: 10.32847/business-navigator.64-10.
[38] Stevenson, S., & Liscio, E. (2024). Assessing iPhone LiDAR & Recon-3D for determining area of origin in bloodstain pattern analysis. *Journal of Forensic Science*, 69(3), 1045-1060. doi: 10.1111/1556-4029.15476.
[39] Tredinnick, R., Smith, S., & Ponto, K. (2019). A cost-benefit analysis of 3D scanning technology for crime scene investigation. *Forensic Science International: Reports*, 1, article number 100025. doi: 10.1016/j.fsir.2019.100025.
[40] Vargas, B.F., dos S., Coutinho, M.A., & Coutinho, F.S. (2021). 3D printing in forensic medicine and crime solving: Integrative literature review. *Revista De Medicina*, 100(1), 62-69. doi: 10.11606/issn.1679-9836.v100i1p62-69.
[41] Vidoli, G., Devlin, J., Watson, J., Kenyhercz, M., & Keller, J. (2020). *Implications of three-dimensional laser scanned images for the criminal justice system*. Washington: National Institute of Justice.
[42] Villa, C., Larsen, S.T., Hansen, K., Rohde, M.C., Haahr, M.K., Boel, L.W.T., Leth, P.M., & Jacobsen, C. (2024). Forensic imaging in Denmark, 20-year-experience: Status and future directions: A positional statement from the Danish Forensic Imaging Group, of the Danish Association of Forensic Medicine. *Forensic Imaging*, 36, article number 200583. doi: 10.1016/j.fri.2024.200583.

Інноваційний потенціал 3D технологій у розслідуванні злочинів

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Анотація. Актуальність статті зумовлена необхідністю постійної актуалізації спеціальних знань криміналістів та впровадження новітніх технологій у діяльність розслідування злочинів. Метою цього дослідження було критичне вивчення передового досвіду застосування 3D технологій у розслідуванні злочинів. Шляхом системного огляду наукових досліджень, в яких репрезентовано різні методики застосування 3D технологій у розслідуванні злочинів доведено, що в науковому дискурсі спостерігається пожвавлення дискусії про застосування 3D технологій. Вчені відзначають ряд переваг від застосування таких технологій: 3D сканери дозволяють створити цифрову модель місця злочину; 3D реконструкції дають змогу визначити послідовність дій, встановити причинно-наслідкові зв'язки, відновити первинний вигляд пошкоджених об'єктів; друковані 3D моделі наочно демонструють певні ознаки об'єктів. Аналіз наявної літератури з тематики дозволив систематизувати застосування 3D технологій у розслідуванні злочинів та виокремити три головні напрями застосування 3D технологій у практиці розслідування злочинів: (1) візуалізація місця події; (2) класифікація, ідентифікація та діагностика об'єктів; (3) реконструкція об'єктів чи подій. Швидкість, точність, безпечність, неруйнівний вплив та багато інших критеріїв, які зазначають вчені вказують, що 3D інновації можуть стати важливим допоміжним інструментом для криміналістів, слідчих, прокурорів. Водночас результати проаналізованих випробувань демонструють певні обмеження та проблеми, які супроводжують практику застосування цих інновацій. В результаті проведеного огляду наукової літератури зроблено висновок, що трансфер 3D технологій у діяльності правоохоронців неможливий без розуміння економічних та соціальних вигод інноваційного інвестування. Визначено зміст цих вигод та система заходів, спрямованих на інтенсифікацію інноваційних процесів у цьому напрямі. Практичне значення дослідження полягає в тому, що отримані результати можуть бути використані підрозділами техніко-криміналістичного забезпечення та органами досудового розслідування під час розробки новітньої тактики збирання доказів, фіксації, обробки та використання інформації про кримінальні правопорушення для потреб кримінального правосуддя

Ключові слова: 3D інновації; віртуальна модель; досудове розслідування; докази; місце злочину; цифрове документування