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Роль виртуальной реальности в совершенствовании судебной экспертизы по делам о нарушении правил охраны труда: научный обзор

С.О. Касенова, Д.В. Воеводкин

Академия правоохранительных органов при Генеральной прокуратуре Республики Казахстан, Косшы, Республика Казахстан

АННОТАЦИЯ

В статье рассматриваются перспективы внедрения инновационных технологий в виде виртуальной и дополненной реальности при проведении судебных экспертиз в контексте исследования отдельных категорий уголовных дел, в частности о нарушениях правил охраны труда; раскрыты проблемные аспекты при проведении осмотров места происшествия в труднодоступных местностях с возможными рисками для людей.

На основе обобщения научных трудов и практического опыта зарубежных стран проведён анализ в области применения новшеств научно-технического прогресса в судебных экспертизах. В результате предложен алгоритм проведения судебной экспертизы в области охраны труда с использованием технологии виртуальной реальности, а также применения его в дальнейшем в судебных процессах. Предложенный алгоритм может служить основой для разработки более эффективных и безопасных методов проведения судебных экспертиз в условиях виртуальной реальности.

Развитие детальных трёхмерных моделей телесных повреждений, симулирующих реальные сценарии происшествий, позволит достичь более точной и объективной оценки повреждений. Кроме того, использование технологии виртуальной реальности в сравнении с традиционной экспертизой обеспечит высокую точность измерений, охват всего объекта исследования; значительно сократит время работы, а также сохранит всю полученную информацию в первозданном состоянии, что является отличной возможностью для воссоздания места происшествия в режиме реального времени.

Отмечается, что внедрение виртуальной реальности в судебную экспертизу по делам о нарушении правил охраны труда будет способствовать эффективности, объективности, полноте и достоверности не только заключений судебных экспертиз, но и судопроизводства в целом. Кроме того, данное направление развития технологий представляет значительные преимущества для судебной системы, способствуя как сокращению времени, так и справедливому судебному разбирательству по делам в области охраны труда или иных категорий уголовных дел.

Ключевые слова: виртуальная реальность; судебная экспертиза; охрана труда; технологические инновации; виртуальные очки; лазерное сканирование; трёхмерные модели телесных повреждений.

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Role of virtual reality in advancing forensic medical examination in cases of occupational safety violations: a review

Samal O. Kasenova, Denis V. Voyevodkin

Academy of Law Enforcement Agencies Under the General Prosecutors Office of the Republic of Kazakhstan, Koshy, Republic of Kazakhstan

ABSTRACT

This article discusses the prospects for introducing innovative technologies in the form of virtual and augmented reality when conducting forensic examinations of certain categories of criminal cases, such as violations of labor protection rules. Problematic aspects are revealed when conducting inspections of crime scenes in hard-to-reach areas with possible risks to people.

Based on a generalization of scientific works and practical experience of foreign countries, the application of innovations in scientific and technological progress in forensic examinations were analyzed.

The authors proposed an algorithm for conducting forensic examination in the field of labor protection using virtual reality technology, as well as its further application in legal proceedings. The proposed algorithm can serve as basis for the development of more effective and safe methods for conducting forensic examinations in virtual reality.

The development of detailed 3D injury models that simulate real-life accident scenarios will enable more accurate and objective injury assessments. Moreover, compared to traditional forensics, the use of virtual reality technology ensures high accuracy of measurements and coverage of the entire object under investigation, significantly reduces operating time, and stores all received information in its original state, which is an excellent opportunity to recreate the scene of an incident in real time.

The introduction of virtual reality into forensic examination in cases of violation of labor protection rules will contribute to efficiency, objectivity, completeness, and ensuring the reliability of not only the conclusions of forensic examinations but also legal proceedings in general. Additionally, this direction of technology development represents significant benefits for the judicial system, contributing to the reduction of time and fair trials in the field of labor protection and in other categories of criminal cases.

Keywords: virtual reality; forensic expertise; labor protection; technological innovations; virtual goggles; laser scanning; three-dimensional models of bodily injuries.

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虚拟现实在提高违反劳动安全规则案件的司法鉴定方面的作用：科学综述

Samal O. Kasenova, Denis V. Voyevodkin

Academy of Law Enforcement Agencies Under the General Prosecutors Office of the Republic of Kazakhstan, Koshy, Republic of Kazakhstan

摘要

本文介绍在司法鉴定中引入虚拟现实和增强现实形式的创新技术的前景。该研究是在考虑究某些类别的刑事案件，特别是违反劳动安全规则的案件时进行的。文章揭示了在难以到达的地区进行现场检查可能存在的问题。

在对科学研究和外国实践经验进行归纳的基础上，对司法鉴定中科技进步创新的应用领域进行了分析。作者提出了在劳动保护领域利用虚拟现实技术进行司法鉴定的算法，以及该算法在司法程序中的进一步应用。提出的算法可作为开发更有效、更安全的虚拟现实司法鉴定方法的基础。

通过开发模拟真实事故场景的详细三维人体伤害模型，可以对伤害进行更准确、更客观的评估。此外，与传统的鉴定相比，虚拟现实技术的使用将确保测量的高准确性，覆盖整个研究对象，大大缩短工作时间，并以原始状态保存所获得的信息。这是实时重现事故现场的绝佳机会。

作者还指出，在违反劳动保护规则案件的司法鉴定中引入虚拟现实技术，不仅有助于提高司法鉴定结论的效率、客观性、完整性和可靠性，而且有助于提高整个法律诉讼程序的效率、客观性、完整性和可靠性。此外，这一技术发展方向还为司法系统带来重大优势。它既有助于缩短劳动保护案件或其他类别刑事案件的审理时间，也有助于公平审判。

关键词：虚拟现实；司法鉴定；劳动保护；技术创新；虚拟眼镜；激光扫描；身体伤害的三维模型。

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BACKGROUND

This article was conducted owing to modern challenges and needs in forensic medical examination, especially regarding violations of labor protection rules. Technological progress and virtual reality provide new opportunities for increasing the efficiency, objectivity, completeness, and reliability of expert opinions. With increasing labor conflicts and industrial accidents, the use of virtual reality may be beneficial for a more accurate and objective assessment of situations and prevention of possible additional risks, from collecting and analyzing data to drawing conclusions.

Furthermore, this article was performed because of inadequate forensic medical methods to the requirements of current dynamic work environment. Virtual reality enables creating controlled virtual scenarios that replicate real-life working conditions and, in turn, allows experts to simulate and analyze situations more accurately, providing more objective forensic results. We believe that this approach improves examination quality in and contributes to the development of forensic medicine in general and in labor protection in particular.

The present article analyzed the influence of virtual reality on the process and results of forensic medical examination when investigating violations of labor protection rules to increase efficiency, objectivity, and completeness and ensure the reliability of conclusions.

SCIENTIFIC UNDERSTANDING OF THE ROLE OF VIRTUAL REALITY IN THE INVESTIGATION OF CASES OF VIOLATION OF LABOR SAFETY RULES

Ensuring proper safety and labor protection in the constantly changing labor process, labor organization, and technological development is extremely relevant and is of particular importance for reducing the risks of possible industrial incidents. Thus, the transition to new technologies and automation requires constant updating of norms and standards in the field of labor protection.

Moreover, technologies newly introduced at production sites, such as big data processing, blockchain, Internet of things, virtual and augmented reality, three-dimensional (3D) printing, artificial intelligence, and printed electronics, determine the vector of development of forensic examination in the future [1].

The objective need to adapt to changing working conditions, ensure safety in new technological realities, and maintain the social responsibility of modern organizations further indicates an urgent need to review and improve approaches to managing occupational safety and health and studying possibilities of improving forensic examination in cases of their violation.

Failure to comply with established rules and standards in this field can lead to tragic situations leading to harm to the life and health of workers. Investigation of such cases — identifying the causes and conditions that contribute to them — is crucial to ensure adequate safe working conditions and prevent the recurrence of violations in the interests of society, workers, and companies.

Forensic examination is key in investigating violations of labor protection rules and making informed decisions in the case. When investigating violations of labor safety rules at enterprises, difficulties related to production factors arise, which are associated with the destruction of evidentiary items that cannot be restored. Without an examination, investigative bodies are deprived of a comprehensive, complete, and objective understanding of events in cases of violations of labor protection rules. Expert opinions establish the causes and consequences of incidents, which becomes the foundation for making informed decisions. Since the examination results provide conclusions about the extent and impact of violations of labor regulations, the investigative body can rely on this key tool to achieve the objectives of the criminal process.

Concerning the changes and global scaling of scientific and technological progress, including the improvement of the visual and variable component, there is an objective need to further improve the methods of investigating criminal cases for violations of labor protection rules and performing forensic expert examinations.

Expert opinions, including forensic medical reports, are critical in the modern world for criminal prosecution authorities and courts in proving certain circumstances in criminal cases under consideration. As a rule, when making a decision in a case, the court justifies its position based on the expert's conclusion, and if the defense calls the conclusion into question, the court rejects the defense's arguments and argues its viewpoint without grounds to question the expert's conclusions [2].

As an integral element of legal proceedings, forensic examination aims to resolve issues that require specialized knowledge. Currently, this procedure faces challenges, and virtual reality technology can offer innovative solutions. Virtual reality technology is an excellent opportunity to create virtual models of the incident location and reconstruct events with a high degree of realism. Experts have the opportunity to literally "immerse" themselves in virtual space and analyze every element of the event that occurred, which in turn increases research accuracy and significantly reduces the time spent on conducting examinations.

High-tech methods, such as 3D photogrammetry, virtual reality technology, and photorealistic simulation, provide more detailed and accurate reconstruction of events, analysis of injuries, and determination of other circumstances of the incident. With these technologies, forensic experts can visualize the scene of an incident in 3D space, which significantly improves understanding of the dynamics of events and interaction of factors influencing their course. The

proposed approach increases the accuracy and objectivity of forensic examinations and contributes to a more complete investigation of the circumstances of the event under study, which is crucial for identifying the true causes and consequences of the incident and the perpetrators and bringing them to justice. Thus, the integration of high-tech analysis methods into forensic practice may be promising in improving forensic science and activities (Table 1).

Before considering the potential applications of virtual reality in criminal justice, understanding of the basics of this technology is critical. The term "virtual reality," first coined in the late 1980s, refers to an artificial, 3D, and interactive environment that replaces the physical environment. That is, it is a computer-generated area that simulates the real world and enables users to interact with it [3]. Human-computer interaction in virtual environments occurs through immersive technologies such as head-mounted displays (Fig. 1). This experience immerses the user in the virtual world for real time interaction with it [4]. Immersion and presence in a virtual environment are created using various sensory modalities, such as visual and auditory input, and additional elements including haptic gloves. In the scientific literature, "virtual reality" is defined as "an interactive environment technically constructed using computer tools as the generation and operation of objects, real or imaginary, based on their graphical representation, simulation of their physical properties and the ability to influence and be present independently in space, as well as the creation of such objects using special computer equipment" [5].

Currently, there are several precedents for the situational type of research and detailed expert opinion in the investigation of cases using virtual reality technologies. Virtual reality and environments have wide application in various fields, including medicine, psychotherapy, education, entertainment, etc., and can be used in the following:

- Phobia treatment in psychotherapy to create controlled virtual scenarios that help patients overcome their phobias and anxieties through exposure [6].
- Affective influence to convey emotions and create affective scenarios which can be useful in various fields, including research and teaching [7].
- Pain treatment by managing the pain of patients by providing them with visual and auditory distractions [8].
- Medical training, for example, in surgery, during which trainees can interact with virtual models and scenarios, improving their skills before applying them in practice [9]. Thus, in Italy, Great Britain, and other countries, the problem of cardiovascular diseases is serious, which leads to a high mortality rate because of a lack of knowledge and fear of people to provide first aid. The Resuscitation Council has solved this problem by creating a modern educational product for teaching citizens cardiopulmonary resuscitation skills using an accessible and effective virtual environment. Virtual reality has simplified and reduced the cost of the learning process, while increasing significantly its effectiveness [10].
- Conducting a study of the body by scanning.

Fig. 1. Man in virtual reality system.

Table 1. Integrating virtual reality technologies into forensics

Type of expertise	Simulation	Virtual reality capabilities
Forensic medical	Trauma modeling	Creation of three-dimensional models of injuries with their effects on the body
	Medical data visualization	Improvement of medical data visualization for more accurate results analysis
Forensic technical	Reconstruction of events	Simulation and reconstruction of an incident scenario, including the use of technical means
	Testing technical hypotheses	Testing hypotheses regarding the technical details of the virtual environment
Forensic criminalistic	Crime scene	Creation of a virtual model of a crime scene with detailed data on traces and evidence
	Crime reconstruction	Event reconstruction and trace analysis
Forensic psychiatric	Research of psychological aspects	Creation of scenarios, testing of behavioral reactions and analysis of the mental state of the defendant
Forensic economical	Financial data analysis	Visualization and analysis of complex financial transactions and data
Forensic graphological	Handwriting analysis	More accurate analysis and comparison of handwriting

Technical aspects of photography, such as orthogonality and depth of field, are critical to reliable measurements. Personnel training is important; however, visualizing a 3D injury on a two-dimensional (2D) photograph involves a loss of information. Overcoming the shortcomings of 2D photographs is possible with the use of 3D photogrammetry, which transforms people and their injuries into 3D space. Creating a photorealistic 3D model involves taking and processing photographs in special software. These technologies enable to reconstruct the sequence and nature of bodily injuries and identify unidentified corpses that have undergone severe deformation as a result of various events, such as exposure to high temperatures during fires, the aquatic environment during a long stay in water, etc. [11].

The Institute of Forensic Medicine at the University of Zurich conducted an experiment using a mannequin with tattooed wounds, which was documented using 3D photogrammetry. The results showed that 3D measurements of injuries were more accurate than standard forensic medical photographs. In a subsequent study, the generated 3D model was examined in virtual reality, and its results were compared with those of the previous study. The main objective was to evaluate injury measurement accuracy in virtual reality technology compared with images and photogrammetric methods on a computer screen. Measurements obtained using virtual reality have been found to be more accurate than those on forensic photographs, but slightly less accurate than photogrammetric measurements on a computer screen [12].

Determining the exact extent of bodily injuries is crucial in forensic examination. The current standard method for documenting injuries is the use of photographs with a scale that measures the injury in the image. Technical photographic characteristics such as orthogonality, depth of field, and clarity within the area of interest are critical to obtaining accurate measurements.

The use of virtual reality in forensics can provide additional tools for documenting and measuring injuries. This can be done by the following:

- Three-dimensional scanning of injuries using 3D scanners to create accurate 3D models of injured areas and their subsequent loading into a virtual environment for further analysis.
- Interactive virtual reality scenarios where experts can manipulate images of injuries, change viewing angles, and zoom to obtain more accurate measurements.
- Integration of virtual environments with medical data, such as computed tomography or magnetic resonance imaging, to create a more complete presentation of the injury and its extent.
- Adding labels and measurements directly in the virtual environment, which will provide a more accurate and convenient environment for working with data.
- Using virtual reality to train forensic experts, create virtual study case for practice, and improve skills in injury assessment.

Overall, virtual reality can significantly improve forensic examination processes through the use of more accurate data to measure and document traumatized areas. However, to ensure high accuracy and reliability of data, systems should be carefully calibrated and verified. In 2012, a mediated reality system was developed to enable collaboration between investigators on the scene and fellow experts working remotely. This technology solution was designed for effective collaboration and cooperation, allowing experts to be virtually present at the scene of a crime even while located at a great distance from the event under investigation [13].

ALGORITHM FOR INSPECTION OF AN INCIDENT SITE BY PREJUDICIAL INVESTIGATION AUTHORITIES USING VIRTUAL REALITY TECHNOLOGY AND 3D MODELING

The use of this kind of technology in cases of violation of labor protection rules is because of challenges with the physical presence at the crime scene, owing to the risk of infection and possibility of evidence destruction, especially after time has passed since the discovery of the body or the crime scene [14]. This risk increases with time and the number of people present at the incident location [15]. Additionally, the ability to stay and visit, including repeatedly, the original scene is complicated for various reasons [16]. A notable example is the tragedy that occurred at the Kostenko mine in Karaganda, Kazakhstan, on October 28, 2023, which emphasizes several problems when inspecting the scene. An explosion and fire at the mine left 46 miners dead. The cause was presumably a gas methane explosion in the lava. To adequately understand the use of virtual reality technology in studying the tragedy causes, we propose an inspection algorithm of the incident scene by pretrial investigation authorities (Table 2).

Creating a virtual copy of the scene. A virtual copy of the explosion and fire scene should be created using 3D scanning and photography technologies. This will provide a more detailed and accurate presentation of the scene. Creating a virtual replica of an explosion and fire scene using 3D scanning and photography technologies represents an innovative approach to accident reconstruction. The process begins with the use of specialized 3D scanners that capture precise geometric data of the environment, including landscape details and objects on the scene. Furthermore, photography is performed to detail the textures and colors of the scene. Then, this data is combined into a single 3D space, creating a virtual model that accurately reflects the actual proportions and details of the incident location. This method allows researchers and experts to walk virtually through the scene, study the dynamics of events, analyze damage, and conduct more accurate incident

Table 2. Algorithm for reconstructing a picture of a mineshaft explosion scene

Title	Justification
Data collection	Collection of all available data about the event, including photographs, videos, plans, and other documents. This data will be used as a starting point for a virtual recreation
Three-dimensional scanning	Use of 3D scanning technology to create an accurate three-dimensional model of the crime scene (includes scanning of surfaces, objects, and structures)
Virtual explosion simulation	Using virtual explosion simulation software. Determination of explosion parameters, such as strength, direction, impact radius, and other characteristics
Environmental recreation	Collection of virtual copies of the environment, including geographic features, buildings, equipment, and other elements that may have influenced events
Adding impact factors	Integration of virtual traces of gases, temperature changes and other factors characteristic of an explosion. This can help to understand better the consequences of the event
Virtual interview with witnesses	Virtual interviews with the event witnesses to obtain their perception of the event and additional details
Testing various scenarios	Conducting virtual tests simulating various explosion scenarios and their impact on the environment
Data visualization	Create visual representations of acquired data, including virtual maps, three-dimensional graphs, and animations to visualize events better
Interaction with the virtual scene	Development of interactive capabilities for interacting with the virtual stage. Users can move around the scene, zoom objects, and analyze details
Sharing results	Providing access to the virtual scene to all investigation participants to share information and collaborate

reconstructions. This technology is crucial for forensic research, training emergency personnel, and improving the overall understanding of security events.

Virtual documentation by replacing traditional documentation methods with virtual analogs. When performing these actions, virtual samples should be recorded, and traces and temperature should be measured using virtual instruments. This step focuses on using virtual tools to create documentation and annotations for objects and interact with virtual data. This may involve creating digital annotations, adding tags to virtual objects, using virtual tablets to enter comments, etc. Examples include creating digital records; entering comments, tags, and other documentation elements that can be used to trace events; recording object parameters; etc.

Virtual reconstruction of the characteristics of an explosion using virtual technologies with further analysis of the impact of the explosion on the environment. Here, virtual simulation of the explosion and analysis of its consequences and impact on the environment and structures are emphasized (Fig. 2) [17]. For 3D explosion modeling, specialized programs such as Autodesk Maya or Blender are used. The process involves creating realistic 3D models of the explosion, considering the physical characteristics of objects and their interactions. Simulation algorithms include factors such as force, pressure, temperature, and shock wave propagation. Real time results are visualized using particle effects and shaders to achieve maximum realism. The model is tested and optimized to balance realism and performance. The 3D explosion model may be integrated with other virtual environments or simulators to create complex scenarios or training sites.

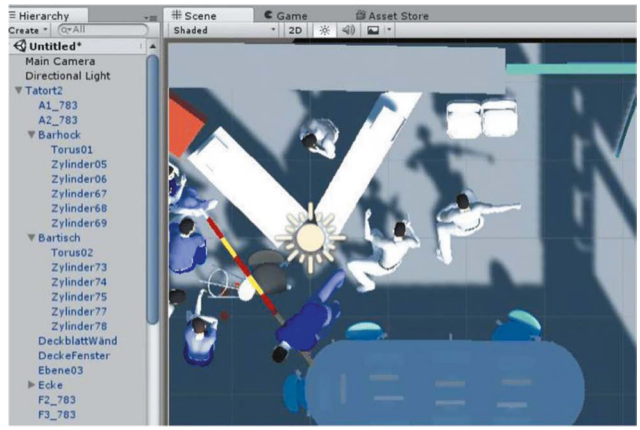

Fig. 2. Simulation of the situation using virtual reality technologies [17].

Interrogating witnesses by placing and immersing them in virtual space to reproduce more detailed visual memories of the event. First, a virtual environment is created using specialized software that simulates the mine space and conditions of the event to conduct a virtual interrogation of witnesses using an innovative method based on virtual reality technologies. Modern virtual reality technologies providing maximum immersion for witnesses, such as VR glasses with head and hand tracking, are being introduced. The tracking system tracks the movements of witnesses, and motion capture technology accurately displays their gestures and facial expressions. Artificial intelligence algorithms are used to imitate witnesses' natural responses to questions, and a speech processing system recognizes oral testimony and converts it into text. The virtual environment is enriched with interactive elements, creating a dynamic virtual interrogation experience. Data recording and analytics provide

documentation of the process, including video, audio, motion data, and analysis of witness behavior.

Virtual analysis of gases to identify the causes of explosion. This stage focuses on studying the chemical compositions and properties of gases that could be associated with the causes of explosion. Examples include modeling the dynamics of gas distribution, analyzing their concentrations in space and time, identifying potentially hazardous compounds, etc. In virtual gas analysis, high-precision mathematical models that factor in the physical and chemical properties of gases are used. Virtual instruments that visualize data from the virtual environment, including gas detectors and analyzers, are being developed. Three-dimensional graphics show the distribution of gases with changing colors and shapes. Signal processing and machine learning algorithms provide automatic data processing, identifying patterns and anomalies. User interactivity includes the ability to change analysis parameters and manipulate data in real time through virtual reality input devices. Considering realistic virtual environment conditions, training the system based on data on the chemical characteristics of gases, and integrating additional virtual tools such as thermal imagers expand the functionality of gas analysis. Such virtual analysis is beneficial for determining the causes of explosions and provides detailed information about the chemical dynamics of gases in a virtual environment.

Interactive scene simulation for navigating a virtual crime scene, highlighting details and interacting with evidence. Interactive virtual crime scene models are used to increase the efficiency and accuracy of the investigation process. Interactive scene modeling involves specialized software to create highly detailed 3D models of a virtual crime scene. Virtual reality technologies, including VR glasses and controllers, provide full interaction with the virtual environment. Interactive elements are created for navigation and highlighting details, and mechanisms for highlighting evidence are integrated. Light and shadow modeling provides realistic scene lighting, and database integration supports real time access to evidence information. Multiuser support capabilities allow investigators to collaborate in virtual space. Optimization for various platforms ensures ease of use of various devices. Staff training includes mastering navigation, identifying evidence, and interacting with interactive elements, facilitating more efficient and detailed investigation of the virtual incident location.

Creating a virtual report for effective information exchange and collective analysis by virtual teams. Virtual reports are digital documents containing detailed information about the scene, virtual models, photographs, animations, and other data collected during the investigation.

The technology allows for easy information exchange between investigative agencies and experts and other participants within the investigation scope, even if they are in different places. Virtual reports allow them to interact with investigation materials, share their observations, highlight important details, and collaborate to analyze data in real time. This promotes faster and more consistent decision-making because virtual reports provide the team with comprehensive information and means to brainstorm the results. Moreover, effective exchange of virtual reports helps to increase the overall transparency of the investigation, minimize possible errors, and identify more quickly the key aspects of the incident.

The option we have proposed is currently a draft algorithm and therefore has not been used in practice. However, we believe that using virtual reality and 3D simulation technologies, e.g., recreating a detailed picture of the incident location of an explosion in a mine, will provide the opportunity to study the scene at any time after initial examination in reality. This is critical in cases wherein it is not possible to reexamine the incident location because of a change in the situation, a threat to the life and health of the inspection participants, or the transfer of the case to an investigator who did not participate in the initial inspection.

Therefore, the use of an algorithm for conducting an inspection of the accident scene in a mine explosion or fire, performed using virtual reality technology and 3D simulation, will significantly improve the investigation progress. Creating a virtual copy of the scene and virtually documenting and recreating the explosion characteristics allows for a more accurate reconstruction of the event. Virtual witness interviews and trace gas analysis in a virtual environment will provide additional detailed data. Interactive scene models make it easier to interact with data. This will provide a more accurate presentation of the incident, improve analytical capabilities, assist in identifying the cause of the explosion, and create safer and more efficient methods for examination of the accident scene in complex scenarios, which will significantly affect the objectivity and effectiveness of the investigation and help in the judicial process.

COMPARATIVE LEGAL ANALYSIS OF THE APPLICATION OF VIRTUAL REALITY TECHNOLOGIES IN FOREIGN COUNTRIES AND KAZAKHSTAN

The use of information technologies in criminal proceedings makes it real in practice, and not illusory and speculative, enshrined in the European Convention for the Protection of Human Rights and Fundamental Freedoms and the right of everyone to a fair and public hearing of a case within a reasonable time, incorporated into criminal procedural legislation. Innovative technologies, such as virtual and augmented reality, provide opportunities in the field of criminal justice. Large technology companies, including Sony, Microsoft, Google, Facebook, and Valve, are presently actively engaged in hardware and software development in these fields.

Research by Australian scientists showed the potential of using VR headsets to improve decision-making in court. Participants in a VR crime scene inspection showed

more consistent verdicts than those who simply looked at photographs. Additionally, VR viewing significantly improved the memorizing of crime scene details, which influenced the quality of verdicts[1]. This indicates the positive impact of information presentation technology under consideration on the perception and interpretation of evidence in trials, thereby providing a complete, detailed, and immersive view of the crime scene and contributing to a more unambiguous and consistent verdict in court.

Crime scene examinations, especially those involving a jury, are rarely conducted on site owing to various limitations. Instead, they use the disclosure of investigative protocols and study of photographs of dubious quality. Scanning a crime scene and allowing the court, jury, and parties to examine it in virtual reality improves the efficiency of forensic examinations by overcoming time constraints and maintaining accurate perceptions of the event.

Australian scientists have revealed that the use of existing crime scene scanning and virtual inspection technologies is much cheaper than organizing a jury visit to the crime scene itself. Moreover, the IT community is showing interest in using virtual reality in investigations, as demonstrated by the game Cyberpunk 2077 from CD PROJEKT RED[2]. The game uses braindance technology, which enables to study the digitized consciousness of an event participant in audio and visual layers and identify biological traces. This can further be used in criminal proceedings, where the sound presentation and additional layers of information can be decisive in criminal cases.

Notably, the use of virtual reality technology in medicine has improved owing to the integration of VR games in rehabilitation after stroke. In 2015, at the Vall d'Hebron Hospital, Barcelona, a woman with paralysis after a stroke regained her motor functions by participating in a VR game. This method, starting from simple stages and progressing to more complex levels including bowling, is a significant advance in the use of virtual reality in medical rehabilitation [18].

In a scientific study, several scientists from the Institute of Forensic Science of the Ministry of Justice of China showed that the reconstruction of a crime scene is crucial in solving crimes, helping to determine the course of events. Noninvasive, high-resolution measurements and in-depth understanding are core aspects of forensic crime scene documentation. However, traditional methods are ineffective for complete reconstruction of entire crime scenes. This study presented a portable system comprising a laser scanner, two handheld structured light scanners, and a low-cost virtual reality headset with a mobile power source for 3D spatial measurements at crime scenes. To demonstrate the practical application, they analyzed a real case to test the feasibility and effectiveness of the system. The system records accurate information about injuries, possible injuring tools, and on site traces. Different types of crime scene evidence can be examined using 3D visualization to create a related event. Data is presented through immersive virtual reality rather than on computer screens. The relationship between chains of evidence allows for complete reconstruction of a crime scene, using the specialized knowledge of experts and forensic computer tools to analyze the causes of the incident and identify suspected offenders. The use of 3D imaging techniques enables a more detailed examination and several useful analyses, such as precise measurements, determination of the relative location of the blood source, and comparison of instruments causing injury [19].

In Kazakhstan, virtual reality technology, having been introduced into the gaming industry, is actively spreading in other areas. In the country's industry, it is used to train personnel in hazardous areas and create virtual manuals for equipment maintenance and repair and in fire safety and emergency response training.

The development of virtual reality technology in proceedings has become a noticeable trend, especially accelerated by the pandemic. Virtual reality has been successfully used to train personnel on industrial safety issues, which is ensured by creating educational programs, visual aids, and simulators to visualize work processes and interact with equipment. An example of the successful implementation of a VR project was the experience of Kazatomprom and Baiken-U. Using LiDar technology and drones, a virtual model of the mine was created, and Oculus Quest 2 VR glasses were used to train and visualize hazardous scenarios at the place of production. This approach is effective in training staff, especially when there are restrictions on inperson meetings[3]. These innovations help improve the understanding of industrial safety, provide realistic interactions with equipment, and save time and company resources. The introduction of VR technologies into production processes is a strategic direction for Kazatomprom, allowing it to manage assets and maintain a leadership position in the global market.

Moreover, the introduction of a virtual autopsy (virtopsy) is being actively discussed in Kazakhstan. A virtopsy is a computer scan of a human corpse and excision using a special 3D program. A similar approach to conducting a virtopsy was previously studied by Kazakh scientists. As a result of the study, the authors attempted to establish regulatory norms of legislation regarding the prospect of using the results of a new 3D method of "autopsy" of a corpse without using a scalpel as evidence in the investigation and trial of criminal cases.

[1] citforum [Internet]. R. Avdeev, "VR technologies of Australian scientists will help jurors make decisions in court [07/29/2021]. Access mode: http://citforum.ru/news/42929/. Access date: 11/29/2023.

[2] cyberpunk [Internet]. Full immersion in Cyberpunk 2077. Access mode: https://www.cyberpunk.net/ru/ru/. Access date: 11/29/2023.

[3] sknews [Internet]. R. Nigmatulin, "Kazatomprom enterprises use virtual reality technologies" [05 Oct., 2021]. Access mode: https://sknews.kz/news/view/predpriyatiya-kazatomproma-primenyayut-tehnologii-virtualynoy-realynosti. Access date: 11/30/2023.

Thus, virtopsy speeds up production (registration or issuance) of the examination, which in turn reduces the time of investigation, eliminates administrative barriers, and minimizes court costs because of the exclusion of repeated examinations and unfounded prosecution. Virtopsy can become a mandatory and effective method for investigating cases of sudden death, unidentified corpse, medical errors, and others, which makes it possible to expand the evidence base using 3D reconstruction along with preserving the original data for auditing [20]. Virtual reality technology covers all sectors of life and represents a technology for creating a virtual environment, whereas virtopsy is a part of medical procedures and research. Furthermore, this position proposed by researchers is critical in improving science and technology in this field.

Therefore, it can be emphasized that the use of information technologies, particularly virtual and augmented reality, provides new prospects in criminal proceedings to ensure fairer and more efficient proceedings. The conducted studies indicate the potential of using virtual reality technologies to improve decision-making by almost all participants in legal proceedings, including experts and specialists.

Virtual reality provides a more complete and immersive view of the crime scene, which contributes to a more accurate perception and interpretation of evidence, which is warranted in situations where inspection of the crime scene by visiting by all participants in legal proceedings is challenging or impossible. Such innovations can significantly increase the efficiency of the judicial process, ensuring more objective consideration of cases and reducing the time for decision-making. The use of innovative technologies in criminal proceedings contributes to the implementation of principles of justice enshrined in international standards and national legislation.

METHODS OF 3D VISUALIZATION WHEN CONDUCTING FORENSIC EXAMINATIONS

The approaches used by pretrial investigation bodies when inspecting the incident scene during the investigation of cases of violations of labor protection rules, which consequences can result in industrial injuries of varying severity or death, are not always accurate. As a rule, owing to the lack of necessary competencies, investigators invite specialists or experts to conduct a crime scene inspection. The subsequent course of investigation of cases depends on the initially collected material; if this stage was disrupted, the subsequent change in the details of the situation limits its further reconstruction and modeling. To overcome this, better decisions should be made to document the crime scene. As part of the study of scientific literature in this field, we identified the most optimal solution among the studies of virtual reality technologies.

Owing to the advantages of noninvasive and rapid high-precision measurements and comprehensive information content, 3D imaging techniques such as laser scanning and structured light scanning have demonstrated their effectiveness in various fields of forensic research. Remarkably, this technology is applied in various industries, including in the forensic science under study (e.g., accident scene reconstruction, evidence analysis, trauma and injury research, facial reconstruction, etc.). Three-dimensional visualization methods, such as laser scanning and structured light scanning, are significant in criminological research and forensic examination and offer significant advantages over traditional capture methods currently used. The characteristic features of the 3D visualization method in forensic activities are the provision of high accuracy of measurements, regardless of the scale of the object under study, which reduces significantly the research time. Additionally, all the information obtained during the study will be preserved in its original state without any outside intervention, which will enable the expert to perform all kinds of manipulations to recreate the overall event in real time.

An integrated 3D scanning platform uses laser scanning techniques to capture all potential evidence from a crime scene. Laser scanning data can be visualized in 3D using a virtual reality headset, allowing users to navigate through a virtual environment, with all 3D simulation data permanently stored and easily shared (Fig. 3) [18]. When investigating cases of violation of labor safety rules, such platforms make it possible to establish the truth and perpetrators of the case with a high degree of probability and, thus, ensure the inevitability of punishment and restoration of social justice.

For clarity, we review several options for using methods in this field:

- Restoration of working scenarios, according to which the expert is provided with a resource for extracting predetermined factors that act as a predicate for violation of labor protection rules.

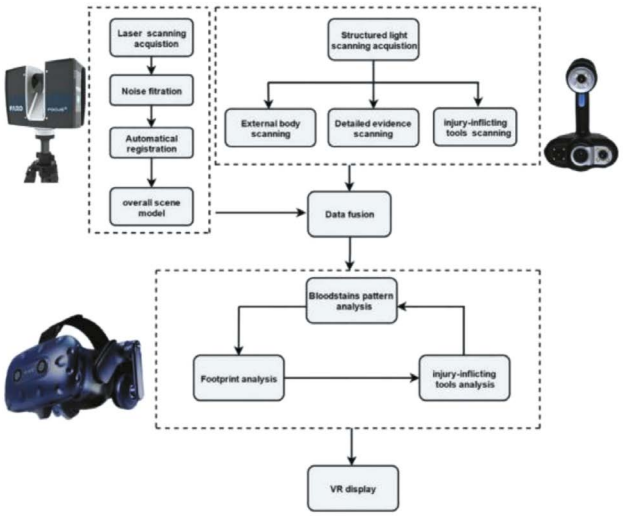

Fig. 3. Scheme of the integrated 3D scanning platform [18].

- Identification of dangerous zones with an increased risk of injury, which implementation represents an excellent symbiosis of the traditional method with a technological breakthrough and will eliminate the probability of exposure to external threats to a participant included in the scope of the investigation of a criminal case.
- Optimize the workspace by assessing the quality of compliance with established standards; experts using 3D visualization can conduct an analysis aimed at improving the workplace conditions.
- With the use of 3D visualization, the expert has an opportunity to document the situation at the scene of the incident in its original state, while information about it is not subject to any changes; accordingly, the use of the method eliminates corruption components.

Thus, in addition to providing accurate forensic data, integrated 3D scanning platforms support proactive safety measures at the enterprise.

CONCLUSION

In the modern world, virtual reality is an innovative tool that has significant potential for improving forensic examination in cases of violation of labor protection rules. This scientific review highlights key aspects of the impact of virtual reality technology on court proceedings and forensic methods in occupational safety.

A virtopsy using virtual reality technologies opens up new prospects for realistic reconstruction of incident scenarios and reconstruction of incidents related to violations of labor protection rules. This provides forensic experts with more accurate tools for analyzing incidents and improves understanding of the impact of violations on victims and witnesses.

Training forensic experts using virtual reality can significantly enhance their skills by providing hands-on skills and experience in realistic environments that are challenging to replicate in traditional training environments.

Thus, the introduction of virtual reality into forensic examination in cases of violation of labor protection rules contributes to efficiency, objectivity, and completeness and ensures the reliability of the conclusions of forensic examinations and legal proceedings. In addition, this direction of technology development provides significant advantages for the judicial system, contributing to the reduction of time and fair court proceedings in cases in the field of labor protection and other categories of criminal cases.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Источник финансирования. Статья подготовлена в рамках реализации научного проекта грантового финансирования по научным и (или) научно-техническим проектам на 2023–2025 годы Министерства науки и высшего образования Республики Казахстан, AP19676297 «Меры противодействия совершению некоторых видов правонарушений посредством чипирования отдельных категорий лиц».

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Вклад авторов. Авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение поисково-аналитической работы и подготовку статьи, прочли и одобрили финальную версию перед публикацией). Наибольший вклад распределён следующим образом: С.О. Касенова — концепция и дизайн работы, сбор и обработка материала, написание текста рукописи, научное редактирование рукописи, рассмотрение и одобрение окончательного варианта рукописи; Д.В. Воеводкин — концепция и дизайн работы, сбор и обработка материала, написание текста рукописи, научное редактирование рукописи.

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ОБ АВТОРАХ

*** Касенова Самал Омарбековна;**
адрес: Республика Казахстан, 021804, Косшы,
ул. Республика, д. 94;
ORCID: 0000-0003-3812-9275;
eLibrary SPIN: 1031-4186;
e-mail: samalkassenova122@gmail.ru
Воеводкин Денис Викторович;
ORCID: 0000-0002-1763-1808;
eLibrary SPIN: 5512-0338;
e-mail: voevodkin.denis@gmail.ru

* Автор, ответственный за переписку / Corresponding author

AUTHORS' INFO

*** Samal O. Kassenova;**
address: address: 94 Republic street, 021804 Kosshy,
Republic of Kazakhstan;
ORCID: 0000-0003-3812-9275;
eLibrary SPIN: 1031-4186;
e-mail: samalkassenova122@gmail.ru
Denis V. Voyevodkin;
ORCID: 0000-0002-1763-1808;
eLibrary SPIN: 5512-0338;
e-mail: voevodkin.denis@gmail.ru