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dr Kaja Kowalczewska
Assistant Professor at the Digital Justice Center,
University of Wrocław
https://orcid.org/0000-0002-9799-9150

mgr Michał Nasiłowski
Research Investigator at the Institute of Law Studies,
Polish Academy of Science
https://orcid.org/0009-0005-5216-3404

POLISH INSIGHTS INTO FORENSIC TECHNOLOGY: THE ROLE OF 3D SCANNERS IN CRIME SCENE INVESTIGATIONS AND INTERNATIONAL CRIMINAL JUSTICE[1]

The integration of 3D scanning technology has transformed crime scene investigations by improving efficiency, precision, and safety in evidence documentation. This paper explores the application of 3D scanners in forensic science and international criminal justice, with a focus on their technical capabilities, benefits, and challenges. Drawing from the experiences of the Polish Police and their collaboration with Ukrainian investigators documenting war crimes, it highlights the critical importance of these devices. Initially used for traffic accidents, 3D scanners are now applied to complex cases such as homicides, disaster sites, and missile strikes.

Using laser beams or structured light, 3D scanners create 360-degree digital reconstructions with a precision of up to 0.1 millimeters. These devices allow investigators to document complex details like blood spatter and structural damage, even in challenging conditions or total darkness. The tamper-proof digital outputs they generate enhance forensic analysis and courtroom presentations. Polish case studies illustrate their effectiveness in scenarios such as building collapses and remote crime scenes, while Ukrainian examples demonstrate their utility in conflict zones, where safety risks and extensive destruction complicate investigations.

Despite their many benefits, 3D scanners face challenges, including sensitivity to adverse weather, high costs, and the need for skilled operators. Combining forensic literature and expert insights, this study emphasizes the transformative role of 3D scanners in advancing modern forensic practices and international justice.

Keywords: *3D scanning, forensic science, crime scene reconstruction, war crimes, evidence preservation.*

1. Introduction

Accurate crime scene documentation is a cornerstone of forensic science and international criminal justice, ensuring that evidence is preserved for effective investigations and successful prosecutions. However, challenges such as human error, safety risks, and time constraints often hinder this process. Advanced technologies, particularly 3D scanners, offer transformative solutions by streamlining investigative workflows.

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This paper examines the functionality and utility of 3D scanners in forensic science, providing a comprehensive analysis of their technical details, advantages, and limitations. The role of these devices in enhancing the efficiency and accuracy of crime scene investigations is explored through the experiences of the Polish Police in handling complex crime scenes. Additionally, the paper draws upon the use of 3D scanners in assisting Ukrainian investigators in documenting crime scenes associated with international crimes arising from the Russian Federation's aggression against Ukraine on 24 February 2022. By doing so, it highlights the value of 3D scanning technology in both domestic and international crimes contexts.

The findings presented in this paper are based on a desk review of expert literature in forensic science and a semi-structured interview with inspector Michał Białęcki, Director of the Criminal Bureau of the National Police Headquarters in Poland. The combination of expert literature review and expert insights ensures a robust analysis of the subject matter, drawing on both theoretical frameworks and practical experience.

This paper is organized into four parts. The first section discusses the importance of visual crime scene inspection, emphasizing the challenges associated with traditional methods. The second section provides a technical description of 3D scanners, detailing their operational mechanisms and capabilities, including the Polish Police experience. The third section outlines the advantages and challenges associated with the use of 3D scanners, with specific use cases from Poland. The final section examines the collaborative efforts of the Polish Police in Ukraine, focusing on their assistance in inspecting international crime scenes and the technical support provided to Ukrainian counterparts.

2. Evolving Practices in Crime Scene Inspection: From Traditional Methods to 3D Scanning

Visual inspection of a crime scene has traditionally been a meticulous and labor-intensive process, central to ensuring accurate documentation, evidence preservation, and the reconstruction of events. The conventional approach requires investigators to follow multiple steps, including providing a general description of the scene, taking detailed measurements and scaling, sketching the layout, and mapping the location of evidence. The process involves photographing the initial state of the scene, revealing latent evidence not visible to the naked eye, re-photographing these findings, and, finally, filming the entire site. Each trace of a crime, its location, carriers, and items potentially linked to the offense must be meticulously documented in an inspection protocol. This documentation includes descriptions, dimensions, and the tools used for discovery [1]. Such a comprehensive approach, while thorough, is time-consuming and prone to human error.

Recent advancements in forensic technology, particularly the use of 3D scanners, have led to provisions that significantly simplify the inspection process [2]. According to §45(6) of the Guidelines No. 3, when inspections are conducted using 3D scanning or other methods outlined in Art. 147 of the Polish Code of Criminal Procedure, the documentation required in the protocol can be streamlined. In such cases, the description focuses only on the method of discovery and securing of traces, carriers, or items. If general, situational, or detailed photographs are included, the protocol need not elaborate on scene descriptions but only on the processes used to reveal and secure the evidence. This provision represents a marked simplification and acceleration of crime scene inspections while maintaining procedural rigor.

With the integration of 3D scanners, the process of crime scene inspection has undergone a major transformation [3]. Modern crime scene protocols now include a dedicated section to record details about the equipment used, such as the type and serial number of the 3D scanner and the operator's information. Once this preliminary documentation is completed, the scanner is employed to capture the entire scene. The use of 3D scanners eliminates the need for manual measurements, as these systems generate precise orthophotos and maps to scale, with accuracy extending to three decimal places. Sketching is also rendered unnecessary due to the scanners' ability to create detailed visual reconstructions. After the scanning phase, forensic technicians proceed to identify additional evidence, such as latent fingerprints, which are then photographed, measured, and described. While 3D scanning does not replace macro-detail photography for specific types of evidence, these photographs can be appended to the final scanned output. This combination of technologies ensures a comprehensive and efficient documentation process, enabling virtual revisits to the scene, virtual procedural experiments and transforming crime scene inspection from a time-sensitive, singular activity to a replicable and detailed analysis [4].

3. Technical Overview and Applications of 3D Scanners

3.1. How 3D Scanners Work

3D scanners are advanced devices designed to capture three-dimensional data of objects and environments using laser beams or structured light. These devices function by emitting a laser beam that generates a “cloud of points”, which envelops the scanned object or area. The system measures the reflection or distance of the laser from the surface, collecting precise spatial data. This information is then processed using specialized software, which recreates the texture and geometry of the scanned object in digital form, ultimately producing an accurate 3D model.

The precision of 3D scanners depends on the resolution settings chosen for the task. At the lowest resolution, the spacing between points can reach 50 mm, while at the highest resolution, it narrows to 0.7 mm. This allows the scanners to capture millions of laser points per second, creating highly detailed and accurate digital reconstructions. The duration of scanning varies based on the resolution and the complexity of the scene, ranging from a few seconds for simple scans to nearly two hours for high-resolution outputs [4]. Some models of 3D scanners include additional features such as thermal imaging cameras, enabling them to operate effectively in complete darkness. The final product is a high-resolution 3D model or point cloud, which is typically saved on portable drives and is often accompanied by a self-starting viewer that facilitates accessibility on standard computers.

3.2. Operational Process of 3D Scanners

The operation of 3D scanners involves a systematic process to ensure comprehensive and precise documentation of crime scenes. This process includes several key steps:

1. **Setup**: The scanner is positioned at carefully selected vantage points, usually on a tripod or a stable surface. For large or complex environments, multiple scans are performed, with each scan overlapping the previous one for seamless stitching.
2. **Scanning**: The device captures the environment by projecting a laser beam or structured light onto the scene. The scanner records the spatial relationships and distances of objects, creating a digital representation of the crime scene. Scanners can operate independently or be connected to peripheral devices such as tablets or laptops for remote control and monitoring.
3. **Data Processing**: The raw data collected during scanning is processed using specialized software, which automatically compiles the information into a cohesive 3D model. This automated process minimizes human interference and ensures accuracy.
4. **Export and Analysis**: Once the 3D model is finalized, it is exported along with visualization software, enabling forensic experts to analyze the virtual reconstruction for evidence, spatial relationships, and environmental context.

Source: Komenda Główna Policji. (2024). Polska pomoc dla Ukrainy [Polish aid for Ukraine]. Gazeta Policyjna. Retrieved from https://gazeta.policja.pl/997/archiwum-1/2024/numer-38-022024-r/241815,Polska-pomoc-dla-Ukrainy.html

3.3. 3D Scanners in Use by the Polish Police

The implementation of 3D scanners by the Polish Police spans over a decade [5]. with newer and more advanced models introduced just before the COVID-19 pandemic. Initially, these devices were employed primarily in traffic accident investigations to document skid marks, deformation patterns, and collision dynamics [6]. Over time, the use of 3D scanners has broadened significantly to include the documentation of homicides, blood spatter analysis, and disaster sites. These scenarios often require meticulous and accurate documentation due to their complexity and severity. 3D scanners have demonstrated their effectiveness across various crime scene contexts, particularly in high-stakes and large-scale cases. Their ability to handle complex and challenging situations with precision makes them indispensable for detailed spatial analysis and reliable evidence preservation [3].

The 3D scanners acquired by the Polish Police are advanced phase-based laser devices designed to enhance forensic investigations. These scanners feature a Class 1 laser with an operational range of 0.3 to 350 meters and a data capture speed of at least 1,000,000 points per second. They offer exceptional measurement accuracy within ±1 mm at distances up to 10 meters, with a 360° horizontal and 320° vertical field of view. Weighing a maximum of 7.5 kg and powered by batteries that provide at least 4 hours of continuous operation, these scanners are portable and efficient. They are equipped with integrated HDR cameras, GPS/GLONASS for positional data, and a digital compass to orient point clouds to true north. Data can be stored on an internal 128 GB memory or SD cards, with files protected by an IP54-rated enclosure that ensures resistance to dust and water, making them suitable for diverse environmental conditions, including temperatures from –10 °C to +40 °C.

The scanners are paired with specialized software that allows for automatic alignment of scans, creation of orthophotos, and export of 3D models in various formats. They also enable measurements within the point cloud and the colorization of scans with integrated photographic data. Additional accessories, such as durable tripods, extra batteries, and MIL-STD-810G-compliant tablets, support seamless operation in the field. These devices excel in challenging environments, including nighttime and large-scale outdoor crime scenes, providing precise and reliable forensic evidence documentation. Features like optional thermal imaging and real-time positioning enhance their versatility for modern investigations.

4. Advantages and Challenges of Using 3D Scanners in Forensic Investigations

4.1. Advantages

One of the primary advantages of 3D scanners in forensic investigations is their ability to significantly increase efficiency [7]. High-resolution scans can capture details of an entire scene in as little as 10–12 minutes, depending on the resolution and complexity of the environment. For example, Polish Police have used 3D scanners to quickly document the aftermath of a catastrophic building explosion in Poznań, where a tenement house partially collapsed due to a suspected intentional detonation, resulting in significant structural damage, multiple fatalities, and injuries, creating a highly hazardous environment for investigators and first responders [8]. The scanner was mounted on a fire department boom to remotely capture data from the unstable structure, minimizing the risk to investigators and ensuring comprehensive documentation. In conflict zones, such as Ukraine, these devices have also been used to document war crimes, allowing investigators to work near frontlines with reduced exposure to danger [9].

Another critical benefit of 3D scanners is their unmatched accuracy and precision. These devices capture spatial measurements with a precision of up to 0.1 millimeters, eliminating the inconsistencies and errors commonly associated with manual documentation methods. For example, 3D scanners have been used by Polish Police to document blood spatter at homicide scenes, providing investigators with reliable data for analysis and reconstruction [10]. The ability to revisit crime scenes virtually enables investigators to analyze details repeatedly, ensuring that critical evidence is not overlooked.

The versatility of 3D scanners further enhances their utility. These devices can operate effectively in diverse environments, including forests and disaster sites. For instance, scanners have been employed to document crime scenes in remote wooded areas where traditional methods would be impractical. They can also function in complete darkness, making them particularly useful in nighttime operations or indoor locations with limited lighting. Additionally, certain models are equipped with thermal imaging cameras, allowing investigators to detect heat traces that might otherwise be invisible.

The legal and forensic benefits of 3D scanners are equally significant. Digital outputs from these devices are tamper-proof, ensuring evidence integrity and preventing manipulation [11]. The high-quality visual reconstructions they produce facilitate detailed crime scene reconstructions, which are invaluable in courtroom presentations [12]. These models also enhance communication among forensic experts, investigators, and prosecutors by providing clear, accurate visual representations [13, 14]. In Ukraine, 3D scanners have been instrumental in ensuring that evidence collected at war crime scenes meets international standards, strengthening the case for future prosecution efforts [15].

4.2. Challenges

Despite their numerous advantages, the use of 3D scanners in forensic investigations is not without challenges. Traditional methods of documentation, which scanners aim to improve upon, often suffer from human error, such as subjective interpretations or inconsistencies in measurements. While scanners mitigate these issues, their operation requires trained personnel.

Environmental and situational factors can significantly impact the performance of 3D scanners, particularly under adverse conditions such as rain, fog, or extreme temperatures. For example, during a forest investigation in Poland, scanners successfully mapped an otherwise inaccessible crime scene despite challenges posed by high humidity and unstable ground. 3D scanners cannot penetrate solid walls, requiring alternative access points to document interiors. In urban settings, such as the partially collapsed structure in Poznań, vibrations from unstable surfaces necessitated adjustments, including disabling GPS systems, to maintain data accuracy. Advanced processing software can mitigate some of these issues during post-production by filtering noise and artifacts, such as stray points from reflections or water droplets. However, over-reliance on these methods can compromise precision.

Documenting crime scenes in wartime introduces additional, unique challenges. Conflict zones, such as Ukraine, present investigators with significant safety risks, including threats from ongoing artillery fire and secondary strikes targeting responders [16]. These risks, although critical, will be explored in greater depth in the next section, which focuses on the collaborative use of 3D scanners in conflict environments.

The cost and accessibility of 3D scanners remain another obstacle. Acquiring these devices, along with their software, accessories, and training, represents a significant investment, estimated at approximately 600,000 PLN (around $150,000). Funding sources in Poland consist of central police budgets and provincial government contributions, while in Ukraine, American donors have helped expand scanner availability. Finally, high-resolution scans generate large data files, requiring substantial storage capacity and infrastructure upgrades to handle the resulting datasets effectively.

5. Collaborative Use of 3D Scanners in Documenting War Crimes in Ukraine

The deployment of 3D scanners has played a crucial role in documenting war crimes committed by the Russian Federation during the ongoing conflict in Ukraine. This work was facilitated by the establishment of a Joint Investigation Team (JIT), initially formed through an agreement signed by Lithuania, Poland, and Ukraine on 25 March 2022. The JIT later expanded to include Estonia, Latvia, and Slovakia on 30 May 2022, followed by Romania on 13 October 2022. On 3 March 2023, a Memorandum of Understanding was signed with the United States Department of Justice, and the Office of the Prosecutor of the International Criminal Court became a participant in April 2022, joined by Europol in October 2023 [17]. The JIT mechanism allows member countries to collaborate closely, ensuring the efficient exchange of information and evidence to facilitate criminal investigations [18].

Through this framework, Polish prosecutors and police officers have supported their Ukrainian counterparts in crime scene documentation. Responding to requests from the Ukrainian Prosecutor General's Office, Polish investigators conducted two missions in Ukraine. The first, in early summer 2022, involved a team of two prosecutors and nine police officers documenting crime scenes in Borodianka and Mykolaiv [19]. A subsequent mission in the summer of 2023 included two prosecutors and ten police officers working in areas such as Sumy, Bilopillia, and Chernihiv. These teams focused on inspecting civilian sites destroyed during the conflict, utilizing 3D scanners provided by the Polish Police [19].

In Ukraine, 3D scanners have proven instrumental in documenting the aftermath of missile strikes, capturing scattered debris, structural damage, and spatial relationships essential for reconstructing events. This technology ensures a level of precision that is critical in war crime investigations, where every detail can influence legal outcomes. By generating accurate three-dimensional reconstructions, investigators can analyse structural damage and evidence placement in ways that would be challenging using traditional methods. These reconstructions are vital for supporting international criminal justice processes, ensuring the integrity and reliability of evidence presented in court.

Investigating in active war zones poses extraordinary risks to personnel. Russian forces have been documented using the "double-tap" method, where secondary strikes deliberately target investigators and responders [20]. These conditions underscore the importance of 3D scanners, which enable the rapid collection of detailed evidence from large areas. By capturing three-dimensional images in mere minutes, these devices allow investigators to minimize their time on-site, significantly reducing exposure to danger [19].

The missions highlighted the 3D scanners' ability to operate effectively in extreme conditions, enabling secure evidence collection even in sites characterized by extensive debris and structural damage. Ukrainian prosecutors and police officers have praised the technology's reliability and efficiency. Building on these successes, the Polish Ministry of Internal Affairs and Administration, in collaboration with the Ministry of Foreign Affairs and the Criminal Bureau of the National Police Headquarters, initiated a project to support the Ukrainian law enforcement. This project, implemented in 2023 and 2024, provided a 3D scanner along with training packages and 16 sets of modern cameras equipped with lenses, flashes, and tripods [21]. More than 20 Ukrainian officers were trained to operate this equipment, further enhancing their investigative capabilities [22].

Beyond improving evidence collection, the use of 3D scanners in wartime enhances the safety of investigators. By reducing the time spent at hazardous sites, this technology helps mitigate the risks posed by active conflict zones. As such, 3D scanners have become indispensable tools for advancing forensic investigations and supporting international justice in the ongoing war.

6. Conclusions

The adoption of 3D scanning technology has significantly improved forensic investigations by addressing long-standing challenges such as human error, time constraints, and safety risks. These tools provide precise, tamper-proof digital reconstructions that enhance the quality and reliability of evidence, supporting both forensic analysis and legal processes.

In wartime settings, 3D scanners have proven particularly effective. Their application in Ukraine has facilitated the documentation of missile strikes, structural damage, and debris fields, ensuring accurate evidence collection under challenging and hazardous conditions. The efficiency of these devices allows for rapid data capture, reducing investigators' exposure to risks while maintaining high standards of evidence preservation.

By meeting the demands of modern forensic science, especially in conflict zones, 3D scanners have become indispensable for ensuring comprehensive documentation and advancing accountability in complex investigative environments.

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Кая Ковальчевська, Міхал Насіловський. Польський погляд на криміналістичні технології: роль 3D-сканерів у розслідуванні злочинів та міжнародному кримінальному правосудді

Упровадження технології 3D-сканування революціонізувало розслідування місць злочинів, покращуючи ефективність, точність і безпеку документування доказів. У цій статті досліджується застосування 3D-сканерів у судовій експертизі та міжнародному кримінальному правосудді із зосередженням на їх технічних можливостях, перевагах і викликах. Спираючись на досвід польської поліції та її співпрацю з українськими слідчими, які документують воєнні злочини, стаття підкреслює важливість цих пристроїв. Спочатку використовувані для розслідування дорожньо-транспортних пригод, 3D-сканери зараз застосовуються для складних випадків, як-от вбивства, наслідки стихійних лих і ракетні удари. 3D-сканери використовують лазерні промені або структуроване світло для створення цифрових реконструкцій на 360 градусів із точністю до 0,1 міліметра. Ці пристрої дають змогу слідчим документувати складні деталі, як-от бризки крові та структурні пошкодження, навіть за складних умов або в повній темряві. Захищені від втручання цифрові вихідні дані, які вони створюють, підвищують якість судової експертизи та презентацій у залі суду. Польські приклади демонструють їх ефективність у випадках, як-от обвалення будівель і віддалені місця злочинів, тоді як українські приклади підтверджують їхню корисність у зонах конфліктів, де ризики для безпеки та великомасштабні руйнування ускладнюють розслідування. Попри численні переваги, 3D-сканери мають свої виклики, включно з чутливістю до несприятливих погодних умов, високими витратами та потребою у кваліфікованих операторах. Інструменти постобробки, зокрема фільтрація шуму та вирівнювання хмар точок, допомагають вирішити ці проблеми, але можуть вплинути на загальну точність. Поєднуючи літературу із судової експертизи та думки експертів, це дослідження підкреслює трансформаційну роль 3D-сканерів у вдосконаленні сучасних судових практик і міжнародного правосуддя.

Ключові слова: *3D-сканування, судова експертиза, реконструкція місця злочину, воєнні злочини, збереження доказів.*