IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 29, Issue 2, Series 1 (February, 2024) 09-15
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Crime Scene Unveiling To Virtual World

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Abstract:
"Time has become constructive that; mankind has been able to discover modern methods to preserve life"
Powerful 3D imaging technologies are being used more frequently as a tool for the investigation of serious crimes as a result of recent improvements in their capabilities and accessibility these days. This study enhances a ground-breaking VR crime scene analysis tool that transforms how the legal system and law enforcement interact with crime scenes. This software presents unmatched advantages to the legal system by painstakingly reconstructing crime scenes in realistic virtual settings.
This software gives law enforcement organizations the opportunity to reproduce and engage with crime scenes in unprecedented detail by seamlessly fusing the fields of virtual reality and forensic science. Additional features that this program can offer include the combination of ground-penetrating radar, fingerprint scanners, ballistics and firearm scanning, along with many more advanced tools to make the investigation smart and much simpler. This study explores the technology's many benefits, such as improved evidence preservation, less crime scene contamination, and faster investigative procedures. By empowering law enforcement, attorneys, and witnesses alike, this research ushers in a new era of technology-driven crime investigation. Thus, this technology has the ability to emerge as a ground-breaking solution when the digital age and criminal justice meet, elevating investigative procedures and redefining the fundamental nature of contemporary crime resolution.

Keywords: *Virtual-reality, Reconstructing crime scene, Technology-driven, Investigation*

Date of Submission: 22-01-2024 Date of Acceptance: 02-02-2024

I. INTRODUCTION

One of the most challenging tasks that investigative officers have during a crime investigation involves proper crime scene reconstruction. This study focuses on a cutting-edge, multidisciplinary approach to improve crime scene scanning and investigation to recreate the crime scene into virtual reality. This innovative method enables law enforcement agencies and forensic professionals to search for evidences using a variety of advanced technologies, including fingerprint scanners, footprint and tire track scanners, photogrammetry, luminol and alternative light, ballistics and firearm scanning, firearm ballistics imaging, chemical scanning, digital evidence scanning, chemical and gas scanning, document scanning, ground-penetrating radar, seismic survey, magnetometry, and utility locators, all combined together.

Currently, techniques such as crime scene sketching, photography, and videography are used for crime scene reconstruction.(Nabar,2002) In the protracted process of inquiry, these outdated methodologies do not offer the investigators with a clear picture of how the crime scene was in the initial stage in order to clarify doubts and correlate the evidences with the scene of occurrence.

In addition to aiding the investigator in gaining a thorough understanding of the crime committed, interpretation of the crime may play a significant part in demonstrating to the judiciary how the crime would have been committed. By interpreting the crime with the aid of the investigator's view, witness testimonies and notion of the crime, this technology enables the judicial system and the investigators to gain that clear picture of how the crime took place. (Deshmukh J, 2023)

The program involves a critical part called lidar-light detecting and ranging, it generates a sensing method used to examine the surface of the earth. This sensor helps in determining and collecting data more quickly with very high accuracy.

There are various advanced tools for collecting evidences in crime scene. They are further discussed below.

1. **Fingerprint Scanners:** High-resolution fingerprint scanners can capture and digitize latent fingerprints found at crime scenes. These digital records are crucial for identifying suspects and linking them to the scene.(Kiltz, S., et.al., 2012)
2. **Footprint and Tire Track Scanning:** Specialized scanners can precisely record shoeprints, tire tracks, and other impressions left behind at the scene. This data aids in determining the movement of individuals and vehicles.(Gamage, R. E., et.al., 2013)
3. **Photogrammetry:** Photogrammetry involves capturing 2D and 3D images from multiple angles to create detailed 3D models. It helps recreate the overall crime scene and its objects with accuracy.(Edelman, G. J., & Aalders, M. C., 2018)
4. **Luminol and Alternative Light:** Luminol and alternative light sources reveal hidden bloodstains and other bodily fluids, which are crucial in understanding the sequence of events and identifying potential victims or suspects.(Webb, J. L., et.al., 2006)
5. **Ballistics and Firearm Scanning:** Scanning technologies can record ballistic evidences such as shell casings, bullets, and firearm details, providing insights into the type of weapons used and the trajectory of shots fired.(Li. D. 2006)
6. **Firearm Ballistics Imaging:** This technology can recreate the path of bullets fired from firearms, assisting in reconstructing shooting incidents. (Braga, A. A., & Pierce, G. L., 2011).
7. **Digital Evidence:** Digital evidence, including data on computers and mobile devices, is scanned and analyzed to uncover valuable information such as communication records, photographs, or documents.(Bulbul, H. I., et.al., 2013).
8. **Chemical and Gas Scanning:** Detecting chemical residues and gases can be crucial in cases involving poisoning, arson, or other hazardous materials.(Chopra, S., et.al., 2003)
9. **Document Scanning:** Scanning and digitizing documents found at the scene or related to the case help investigators reconstruct timelines, motives, and connections. (Docsvault. (n.d.). Document Scanning & Digitization. Docsvault.)
10. **Ground-Penetrating Radar:** Ground penetrating radar (GPR) investigations have the potential to non-destructively detect buried or hidden targets and are therefore often used in forensic research.(Conyers, L. B. 2006)
11. **Seismic Survey:** A technique for determining the detailed structure of the rocks beneath a particular area, which is based on sending acoustic shock waves into the rocks and measuring the signals that are reflected back.(Ashton, C. P., et.al., 1994)
12. **Magnetometry:** An instrument for measuring the magnitude, and sometimes the direction, of a magnetic field. Absolute magnetometers measure the field without reference to a standard magnetic instrument.(Oxford,2019)
13. **Utility Locators:** These devices help identify the location of underground utilities.(Hoffer, T.,2018)

Merits and Demerits

There are many advantages to crime scene recreation in VR and using it on the investigation. Some of them are:

- **Accuracy:** It allows for a meticulous and accurate reconstruction of crime scenes, preserving evidence for later analysis.(Deering , M. 1992)
- **Visualization:** Investigators, judges, and jurors can explore the crime scene virtually, gaining a deeper understanding of the events. (Donalek , C., et.al., 2014)
- **Training:** VR-based recreations serve as valuable training tools for law enforcement and forensic professionals.(Mayne, R., & Green, H., 2020)
- **Evidence Preservation:** It minimizes the risk of contamination or damage to physical evidence.(Wieczorek, T. 2018)
- **Collaboration:** Multiple experts can collaborate remotely, enhancing the efficiency of the investigation. (Gunkel, S. N., et.al.,2018)

A thorough grasp of how the crime might have occurred would be extremely helpful to the investigation process. Investigators can alter the VR reconstruction, adjust factors, and test theories to interpret the crime in various ways. This comprises:

- **Path Reconstruction:** Analyzing the movement of individuals within the crime scene to understand their actions and interactions. (Agosto, E., et.al., 2008)
- **Timeline Reconstruction:** Creating timelines based on evidence to establish the sequence of events.(Hargreaves, C., & Patterson, J. 2012).
- **Bullet Trajectory Analysis:** Determining the origin and path of bullets fired in a shooting incident.(Mattijssen, E. J., & Kerkhoff, W., 2016).

- **Bloodstain Pattern Analysis:** Interpreting bloodstain patterns to reconstruct the dynamics of a violent event.(Attinger, D., et.al., 2013)
- **Virtual Witness Interrogation:** Using VR to virtually interrogation witnesses and suspects within the reconstructed environment. (Sieberth, T., et.al., 2019)

Demerits

- **Health and safety risks:** using virtual reality continuously might cause discomfort, eyestrain, and even other health problems. The virtual stimulation offered in the virtual environment and the user's real movement will be excessive for motion-sick people to adjust to. Indeed, causing discomfort, nausea, and dizziness.
- **Cost and accessibility:** The high cost of the necessary equipment, such as VR headsets and controllers, might act as a barrier by preventing some people or even organisations from using this technology.
- **Restricted access during inclement weather:** atmospheric factors including heavy rain, snowfall, or even fog might affect lidar performance. Water droplets and other airborne particles have the ability to scatter or absorb laser beams, hence decreasing the system's effective range and accuracy.

Although there are certain drawbacks, they cannot outweigh the benefits of this equipment in crime investigation.

II. REVIEW OF LITERATURE

Review of literature provides an understanding about the various techniques and measures used in crime scene reconstruction. Though only one direct study related to the topic have been obtained, a cluster of collective studies on the reconstruction of crime scenes using different scanners and virtual reality in many spheres have taken place.

A study by Kottner, et.al (2023) was conducted to test the Recon-3D app using exemplary scenarios to see whether this technology is generally appropriate for documenting crime or crash scenes. The study revealed that the imaging methodology was easy and quick, allowing anyone to produce 3D documentation at a crime or accident site. Overall, Recon-3D seemed to be a valuable program for forensic investigator.

Another study by Maneli, M. A., &Isafiade, O. E.,(2022) provides the first thorough review of significant milestones in the development of methods for 3D crime scene reconstruction, as well as gaps for improvement and examples of how immersive technology has been applied to improve crime scene findings. This study discovered that using light detection and ranging (LiDAR) scanners and immersive technology, in addition to standard methods, improved crime scene reenactment. The SLR is limited to existing applications that have peer-reviewed articles published between 2005 and 2021. According to the published data, 20.2% of the articles used immersive technologies in crime scene reconstruction, with Augmented Reality (AR) accounting for 15.3%, Virtual Reality (VR) accounting for 75%, Mixed Reality (MR) accounting for 5.9%, and a VR and AR mixture accounting for 3.8%.Finally, the design and important technical trends for crime scene replication using immersive technology are discussed, as well as prospective future research directions.

Scientific and technological advancements have a significant impact on modern society, especially one of its social institutions, law enforcement agencies. The most significant challenge is to incorporate modern computer technology into the training system for law enforcement agents. This technique is related with effective work under conditions that are as close to professional activity as feasible. Mastering such crucial complicated competencies as the capacity to investigate the scene of an incident is a challenge that can only be solved by simulating typical instances of investigating numerous crimes in a complex multi-object environment. The authors created a virtual training ground system for law enforcement agents to imitate the conditions of real-world incident sites using available virtual reality technologies.(Trushchenkov, I., et.al., 2021)

Documenting a crime scene properly and comprehensively is critical to detecting a crime, but the procedure is typically complicated and time-consuming. 3D scanning technology enables the quick capture of highly detailed 3D models of a real space. In recent years, crime scene investigation (CSI) units around the world have increasingly adopted 3D scanning technology to aid in the investigative process. The technology enables detectives to study crime scenes at a later date using a scanned 3D model. Unfortunately, the cost of using this technology remains a barrier for many CSI units. A study by Tredinnick, et.al.,(2019) aims to determine whether investing in this technology leads in an overall benefit for CSI units. To tackle these problems, the researchers created a rigorous cost-benefit analysis algorithm for 3D scanning technology adoption. Actual 3D scanning results from simulated crime scenes, as well as a focus group of crime scene investigators discussing the technology, informed algorithmic considerations. A 100,000-count Monte-Carlo simulation of the devised cost-benefit algorithm allowed researchers to investigate the subject of adoption. The simulation results are offered in both text and an interactive online application. The main highlights of this study are:-

- 3D scanning technology benefits outweigh costs for crime scene investigation units.(Tredinnick, et.al.,2019)
- LiDAR produces higher quality data and more net benefits, for a higher initial cost.(Tredinnick, et.al.,2019)
- Online tool allows customized cost-benefit analysis of 3D scanning adoption for CSI.(Tredinnick, et.al.,2019)

Another study by Wang, J., et.al.,(2019) stated that crime scene reconstruction is important in crime solving because it helps determine the sequence of events. The purpose of forensic crime scene documentation is always to obtain non-invasive, high-resolution measurements and gain more information. However, existing approaches cannot adequately reconstruct entire crime scenes. In this study, we describe a portable system that includes a laser scanner, two hand-held structured light scanners, and a low-cost virtual reality (VR) headset with a mobile power supply for collecting multi-angle and omnidirectional three-dimensional spatial data from crime scenes. To show practical application, a real-world example was analyzed to ensure the system's viability and effectiveness. The system collects reliable data about decedent injuries, potential injury-inflicting tools, and on-site traces. Three-dimensional visualization can be used to study multiple forms of evidence from a crime scene in order to construct a cohesive tale. The data is provided through immersive VR rather than on computer screens. The interaction between evidence chains allows us to rebuild a complete crime scene, using experts' specialized expertise and computer-aided forensic tools to analyze the sources of damage and identify suspects. The utilization of three-dimensional imaging techniques enables for a more in-depth scan and a variety of relevant analysis, including accurate measurement, relative blood source location determination, and injury-inflicting instrument comparison.

In another study, the authors investigated the use of LIDAR scanning and virtual reality to improve crime scene documentation and assessed its usefulness. Modern technologies are used to improve the quality of criminal investigations. Documenting crime scenes is critical to the investigation and prosecution of criminal cases. Traditional techniques of crime scene documentation, including as photographs, sketches, and written notes, have limits in terms of accuracy, completeness, accessibility, and the risk of losing important evidence. 3D data capture systems provide precise scene capturing without the spatial distortion effects present in 2D photographic records. This study investigates the use of LIDAR scanning and virtual reality in improving crime scene documentation. The research evaluates the usefulness of LIDAR scanning and VR walkthroughs, as well as the usage of evidence tagging to improve crime scene documentation. It also aids in determining the usability of the VR system for law enforcement professionals. The suggested model confronts various development hurdles, including the high cost and technical complexity of LIDAR scanning, the necessity for efficient data processing and visualization, and the VR system's limited accessibility owing to hardware and software constraints. Through user testing and analysis, the project demonstrated considerable improvements in the accuracy and completeness of crime scene documentation, resulting in a more detailed and immersive investigation experience. The VR system was discovered to be user-friendly and successful in facilitating decision-making and communication among law enforcement officials. Overall, the project provides vital insights that allow you to see through the eyes of a witness by documenting their point of view, assisting with the investigation and comprehension of the occurrence. They can also be used as evidence in court.(Deshmukh, J., et.al., 2023)

Despite the use of LiDAR sensors to reconstruct crime scenes in three dimensions, several research have not considered the possibility of employing Virtual Reality to experience the output. Despite being a technologically advanced country, India does not use immersive technology, which would be beneficial in the crime scene investigation procedure. Compared to first-world countries, where this technique is used in some form. The distinguishing feature between previous research and this current study is the integration of several technologies.

III. OBJECTIVES

1. To recreate a crime scene using virtual reality.
2. To identify the pros and cons of using virtual reality to recreate crime scene.

IV. METHODOLOGY

A qualitative approach was used to collect expert opinions from of various sections of law enforcement, judicial officers and forensic academicians around the globe. The data was collected using semi-structured interview method and their responses were recorded. The obtained data was collected from the personal experiences and interpretations of highly efficient individuals from their own respective fields, which indeed precisely rendered answers in connection with the requirement.

Futher, to generate the digitally recreated crime scene prototype, the researchers first scanned a mock crime scene setup at the Kerala Police Academy using the LiDAR sensor in the iPhone 12 Pro with the help of meta scanner application. The scenario was then built using Unity software in the presence of a software specialist. To observe the desired output in virtual reality, Oculus Quest 2 console was used.

V. RESULTS AND DISCUSSION

The obtained data was analyzed using thematic analysis and based on the expert opinion, various repeated themes were identified and they were further discussed.

The following are the themes:-

- Accuracy in reconstruction
- Digital preservation of evidence
- Integrity preservation of crime scene

Accuracy in reconstruction

The most challenging part an investigator faces throughout an investigation is accurate crime scene reconstruction. Most of the times crime scenes cannot be accurately reconstructed, as no accurate photographs of the crime scene will be available. Sometimes, even any photographs won't be there because they may have been damaged or went missing.

This virtual reality crime scene reconstruction device helps in proper and accurate reconstruction of a crime scene through 3D scanning. Experts pointed out that such reconstructions of crime scenes and observing it through virtual reality would greatly benefits the investigators in investigation , especially when the investigation team changes. Further in reinvestigation of cold cases ,it would be helpful as the crime scene is not available.

One of the expert claimed that this would be "the best solution for police investigation" as it recreates the crime scene in an accurate way and also allows interacting with the scene.

Researchers of this study were able to maintain 60% accuracy of reconstruction of a mock crime scene in the prototype of this device. Using appropriate LiDAR and other sensors in the presence of specialists could increase reconstruction accuracy to 80-95%.

Digital preservation of evidence

Another major problem investigators encounter is the appropriate preservation of evidence. Even while this virtual reality crime scene reconstruction device does not retain the evidence physically, it benefits a lot by saving these evidences digitally. This could be useful to limit the tampering of crime scene evidence, which could be manipulated by clearing leading evidences from crime scene, and also aid in memorizing the evidences in crime scene that could possibly be missed out in the initial crime scene inspection.

One of the specialists stated that "this method will greatly aid in evidence preservation because it enables for the digital preservation of evidence". And another expert said that "virtual reality crime scene reconstruction and digital preservation of evidence by this manner the evidential value improves, and the investigating officer may even bring it to the court as evidence".

Researchers were able to keep 45-65% of accuracy in digital preservation of evidence in the prototype of virtual reality crime scene reconstruction device. Proper usage of LiDAR scanning, with the support of specialists, can help boost this percentage to 85-95 in the future.

Integrity preservation of crime scene

One of the most challenging aspects of crime scene reconstruction is preserving integrity. Experts pointed out that majority of cases are not solved because of improper crime scene investigation and missing out of crucial evidences during initial crime scene inspection. Through its integrity preservation of crime scene "this gadget will aid in crime investigation since it allows investigators to return to the crime scene numerous times to gain a better understanding of the crime scene and capable of comprehending a crime scene in several dimensions" stated by another expert.

One of the expert said that through the preservation of integrity of crime scene through virtual reality crime scene reconstruction device can be quite useful in criminal investigation as this technology can assist investigator in locating evidences that was missed during initial inspection.

Another expert claimed that in some cases, forensic experts only attend the crime scene in order to correlate the evidence obtained. "This technology will further aid the forensic experts in determing the precise location of things present in crime scene", It allows them to easily correlate the evidences even without going into the actual scene of the occurrence, and thus saving time and money.

By keeping the integrity of crime scene, it helps to retain memory of crime scenes, helps in correlating of witness statements, and it could even eradicate the shortcomings of a regular crime scene sketch. This essentially increases its validity during court proceedings allowing proper administration of justice, claimed one of the specialists.

In conclusion, a revolutionary approach to contemporary forensic investigations is crime scene reproduction through virtual reality, assisted by a variety of advanced scanning technology. It completely alters the manner in which the evidence is preserved, analyzed, and understood. This technique improves the accuracy and transparency of crime investigations, ultimately aiding in the pursuit of justice by submerging investigators and legal experts in very realistic virtual crime scenes.

Thus, the obtained data was analysed with thematic analysis which helped the conclusion in articulating findings.

VI. FINDINGS

Based on the thematic analysis the following are findings of the study:-

- The reconstruction of a crime scene becomes simple and precise through the use of this method.
- It assures the digital preservation of evidence.
- It limits the possibility of tampering with evidence from the crime scene during the subsequent investigative process
- It will aid the forensic experts in determining the precise location of things present in crime scene and help them to correlate the evidences obtained in crime scene.
- It helps to keep the crime scene in its original condition.
- It aids investigators in revisiting the crime scene at any point during the investigation.
- It provides information about the crime scene when reinvestigating a cold case.
- It aids in the correlation of witness testimony concerning the crime scene.
- It creates a walk-through for training purposes.

VII. SUGGESTIONS

Thus the findings of this study helped the researchers in providing adequate suggestions. The suggestions are divided into two divisions:-

1. Suggestions provided by expert
2. Suggestions provided by the researchers

Expert's suggestions:-

- Police officers who attend the crime site first should be trained to ensure evidence preservation and not tamper with evidence when scanning the crime scene with this technology.
- A wall projection of the reconstructed crime scene can be done while addressing a class of students at the same time for training purposes
- Constructing a curriculum criterion so as to train investigating officers in practicing a systemized procedure in the reconstruction of crime-scene.
- The most crucial thing to remember when employing this in a crime scene, such as a murder, is that the scene should be scanned before removing the dead corpse, by conducting it this manner, the evidential value improves.
- It would be more convenient in the future if the 3D model of this virtual reality crime scene reconstruction could be displayed in a holographic format.

Researcher's suggestions:-

- Every police officer should be in touch with the latest technologies.
- A database of weapons should be uploaded to the software in order to make it easier to determine which weapon was used at a shootout crime scene.
- Touch sensors could be added to the device in the future to sense the items during interaction with the scene.
- Advanced voice aid technology, along with this virtual reality crime scene reconstruction gadget, would be beneficial to the user.
- Investigating officers could be equipped with specs like meta glass with built-in scanners during crime scene inspection to make crime scene scanning more accurate and capture the incident from numerous viewpoints.

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