

ORIGINAL ARTICLE

Documentation and Preservation of the Evidences and Reconstruction of A Crime Scene using Augmented Reality, Virtual Reality and Synthetic Reality: Introducing Crime Scene DPR System Bringing the Jury to the Crime Scene

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ABSTRACT

A crime scene, which is the place where a crime has occurred, is suspected of having been committed, or where evidence of a crime has been found, is an essential part of an investigation because it contains all the important details related to the crime. A careful examination of the crime scene can reveal the potential modus operandi of the criminal and establish the Corpus Delicti in court.

The first visit to a crime scene is the investigator's most crucial and often only real opportunity to observe, record, collect, and preserve evidence in its original state. Any subsequent visit holds little to no value, as the scene is usually disturbed, compromised, or altered, either intentionally or unintentionally. Thus, recording a crime became an extremely important step. The typical ways of documenting the crime scene only allow us to view the documents physically; we are unable to provide a visual or allow us to walk to the real crime scene. To help with the investigation, it is crucial to take pictures of the crime scene and any possible evidence.

Virtual reality and augmented reality are in high demand right now. Whereas Augmented Reality incorporates a real-world background, Virtual Reality presents an entirely virtualized version of the situation. Virtual reality (VR) is a kind of

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sophisticated user interface in which the user interacts with a real-time simulation of a world using all five senses: taste, smell, touch, hearing, and sight.

A novel approach to criminal investigation that has promise for increased efficiency is the 3D reconstruction and visualization of criminal scenarios, such as assaults, collisions, and homicides. AR and VR are examples of contemporary 3D recording and processing techniques that are utilized to create an accurate and immersive virtual environment. Conversely, multiple points of view are possible while immersed in a virtual environment.

KEYWORDS

• Crime Scene • Reconstruction • Augmented Reality • Virtual Reality
• 3D Capturing

INTRODUCTION

Forensic science, sometimes referred to as criminology, is the application of science to criminal and civil law, mainly on the criminal side during criminal investigations, as determined by the legal requirements of admissible evidence and criminal procedure.¹

Forensic scientists gather, store, and review scientific evidence throughout an investigation. While some forensic scientists gather evidence directly from crime scenes, others work in labs and examine evidence that has been submitted to them by others. Others analyze financial, banking, or other numerical data as consultants for the government, private sector, or academic institutions in order to use it in financial crime investigations.²

In addition to working in a laboratory, forensic scientists may work for the prosecution or defense and provide expert testimony in both civil and criminal cases. Although technically any field can be considered forensic, certain subfields have evolved over time to encompass most forensic-related cases³. The name “forensic science” is a combination of the Latin words *Forensis* and *science*. The first, *forensic*, refers to an in-depth discussion or review. Due to the frequent staging of trials in front of large crowds in the ancient world, it has strong judicial overtones.⁴ The second is *science*, which is related to the scientific method, a methodical approach to learning, and is derived from the Latin word for “to know.” When taken as a whole, forensic science refers to the application of scientific procedures and methodologies to solve crimes.⁵

Crime Scene

A crime scene is the place where a crime has occurred or where evidence related to the crime is found. It is the starting point of any investigation and can include multiple locations depending on the nature of the crime. No two crime scenes are ever the same, and they involve not just the physical area but also people and objects present. Proper protection of both the scene and everything within it, especially people, is essential to preserve evidence. Every place the suspect or victim moved through during the crime is considered part of the crime scene.^{6,7}

Introduction to AR (Augmented Reality) & VR (Virtual Reality)

The unpopular reality of taxpayers we see is the interactive realization of the real world where computer-generated perceptual knowledge is used to add things to the real world, sometimes involving multiple senses, including olfactory, haptic, somatosensory, and visual. Augmented reality (AR) technology combines the real and virtual worlds, enabling real-time interaction and precise 3D registration of virtual and virtual objects. Obscured sensory information can be helpful or harmful. These experiences are so closely related to the real world that they are considered completely rooted in it. The actual unpopularity of taxpayers we see is changing the perception of real-world space, while virtual reality replaces the user's real estate with a simulated image.^{8,9}

Augmented reality (AR) is a technologically advanced image of the real world created using digital visual components, music or other sensory stimuli. This is a growing trend among mobile computing and marketing

application businesses. One of the main objectives of augmented reality, among the extension of data collection and analysis, is to emphasize certain aspects of the real world, to raise awareness of those qualities, and to produce intelligent and accessible information which can be put in application to real-world systems. Big data can help organizations make better decisions and gain an understanding of customer purchasing practices, among other things.^{10,11}

A virtual experience called virtual reality (VR) can be both similar to and different from the real world. There are many applications for virtual reality in business, education and entertainment. A computer-generated world with realistic-looking visuals and objects is known as virtual reality and gives viewers the impression of being fully involved in their surroundings. Through a virtual reality helmet or headset, this world can be seen. We can use virtual reality to immerse ourselves in video games as if we were one of the characters, to learn how to perform heart surgery and to increase the quality of sports training for performance enhancement. Everything we see is part of an artificially constructed world created with images, sounds and other means.¹²⁻¹⁴

General Techniques Available for Scene of Crime Investigation

A crime scene is a specific location where illegal conduct has occurred, and there is no single correct method for handling each scene. Logic and viability are crucial components of crime scene investigation. Processing a crime scene involves reasoning about what might have happened and examining the viability of that occurrence. After rectifying these issues, a thorough search for missing physical evidence takes place, followed by recognition. The gathered evidence is properly packaged and delivered to a forensic science lab for laboratory based scientific examinations.

Crime scene processing involves two main phases: crime scene treatment, which begins at the crime scene, and the "Laboratory investigation" phase, which begins with the collection and packaging of evidence. The report is then provided to the court for decision-making based on the findings of the scientific investigation. This process helps minimize the need for eyewitnesses and

establish connections between the suspect and victim.^{15,16}

Need of New Technology to be Introduced

History is witness that whenever there is a need, things change according to the time. Presently, when we talk about AR and VR, they are spreading their feet fast in forensic science. AR and VR are one of the emerging fields that are being recognized in forensics as if they will be used at a crime scene for documenting it, a great change in the Criminal investigation and trial system will be observed.

There are some limitations of the currently used techniques for documenting a crime scene and thus there is a need to introduce a new one. In this research article, the author is introducing the new techniques that can be used for crime scene processing, documenting a crime scene and preserving it for good.

At crime scenes, forensic specialists must rapidly and cleanly gather evidence. These users can study, share, and export evidence lists as well as visually tag evidence traces at criminal scenes using a handheld Augmented Reality (AR) annotation tool.¹⁷ Eight end users marked a virtual crime scene while speaking their thoughts aloud during a user walkthrough using this technology.^{15,18} Qualitative findings indicate that annotation could reduce administrative burden, hasten the data collection process, and enhance orientation to the crime scene. While the current prototype had several technological issues related to poor feature tracking, it was discovered that AR annotation was a promising, practical, and useful tool for crime scene investigation.¹⁹

LITERATURE REVIEW

Denney S. *et al.* (2019) explore the use of virtual reality (VR) in crime scene reconstruction and analysis, emphasizing its potential to create immersive, detailed, and interactive reconstructions. They highlight benefits such as allowing repeated visits to the scene, simulating scenarios, and analyzing evidence like bullet trajectories. The paper also notes limitations, including the need for high-quality data, varying VR equipment, high costs, and a lack of standardization. Case studies show VR's effectiveness when the original scene is unavailable. The authors conclude that while

VR can enhance investigative accuracy, further research and standardization are necessary for broader adoption.¹⁹

In the paper "Virtual and Augmented Reality in Crime Scene Investigation and Reconstruction," K.L. Rossmo explores the use of VR and AR technologies to enhance crime scene investigation and reconstruction. He highlights their ability to create immersive, interactive environments that are especially useful in complex or hazardous cases. While noting challenges like the need for high-quality data and equipment reliability, Rossmo suggests these can be addressed with better tools and standardized protocols. Case studies on homicide scenes and bullet trajectory analysis demonstrate the practical benefits of these technologies. He also discusses ethical and legal issues, advocating for clear guidelines to ensure privacy and admissibility in court. Overall, Rossmo sees great promise in VR and AR but emphasizes the need for further research and standardization.²⁰

In "The Use of Synthetic Reality in Crime Scene Investigation," D.F. Houle and R.S. Muzzin discuss how synthetic reality (SR) computer-generated simulations of real world scenarios can enhance crime scene investigation. SR is praised for its ability to create accurate 3D models of crime scenes and evidence, aiding in reconstructions, court presentations, and investigator training. The paper highlights SR's usefulness in complex cases, such as shooting reconstructions and blood spatter analysis, leading to improved investigative accuracy. However, the authors acknowledge issues like data quality demands, technical problems, and difficulty simulating real-world conditions. They recommend advancing SR tools and developing best practices to address these challenges. Ethical and legal concerns, including potential bias and admissibility of SR-generated evidence, are also discussed, with a call for clear guidelines and transparency. Overall, the paper sees SR as a promising tool for CSI, but emphasizes the need for further research and standardization.²¹

Yu *et al.* (2023), in their paper published in Science & Justice, present the Dundee ground truth photography protocol designed to improve how indoor crime scenes are photographed for virtual reality (VR) reconstruction. The authors stress

the importance of accurate and consistent documentation in forensic investigations. Their protocol provides clear guidelines for taking photographs to ensure a complete and reliable visual record of the scene. They tested it on several indoor crime scenes and found it effective in producing high-quality images suitable for VR-based reconstructions. The study shows that using this method can make crime scene reconstructions more accurate and trustworthy. Overall, the protocol offers a valuable tool to support better documentation and analysis in forensic work.²²

In their study published in the Forensic Sciences journal, Galanakis *et al.* (2021) explore various 3D digitization methods for crime scene investigation. Comparing photogrammetry, structured light scanning, LiDAR scanning, and stereo reconstruction, they assess ease of use, cost, accuracy, resolution, and suitability for different crime scenes. The authors find each method has distinct advantages and limitations. Photogrammetry emerges as cost-effective but requires good lighting and may face occlusion challenges. Structured light scanning offers high accuracy and detailed color information but has limited range and requires reflective surfaces. LiDAR scanning excels in accuracy and range but lacks resolution and color capture. Stereo reconstruction is straight forward and cost-effective but lacks precision and requires precise camera calibration. They conclude that while these digitization techniques hold potential to enhance investigations, the choice depends on investigation needs and crime scene characteristics.²³

In 2018, Engström studied the use of virtual reality (VR) for crime scene visualization to help investigators better understand spatial details. A special VR system was developed using 3D modeling software and head-mounted displays, allowing users to explore and interact with crime scenes in an immersive way. When tested with police officers, the VR system showed better results compared to traditional 2D photos and floor plans. Officers reported improved understanding of the scene layout and better identification of evidence. The study highlights VR's potential to transform crime scene investigations by offering more accurate and realistic visualizations, while also pointing out the need to address certain challenges.²⁴

In 2020, Ajah, B.O., Ajah, I.A., & Obasi, C.O. conducted a study focusing on the utilization of virtual reality (VR) and augmented reality (AR) technologies in the investigation and trial of Herdsmen terrorism in Nigeria. By aiming to explore these technologies' applicability in crime scene investigations, particularly in addressing prevalent Herdsmen terrorism, the authors argue for their potential to offer more precise reconstructions, aiding investigators, judges, and juries in decision-making. Through a comprehensive literature review and survey within Nigeria's criminal justice system, the study reveals VR and AR's utility in reducing errors associated with traditional methods. Despite showcasing their effectiveness, the study uncovers a significant gap between awareness and adoption of these technologies in Nigeria. Highlighting the potential benefits, the authors advocate for integrating VR and AR into Nigeria's criminal justice system to enhance investigations and trial proceedings, particularly concerning Herdsmen terrorism cases.²⁵

The paper "Bringing the jury to the scene of the crime: Memory and decision-making in a simulated crime scene" investigates the efficacy of immersive virtual reality (VR) technology in recreating crime scenes for jurors to comprehend and recall events accurately. Participants were randomly assigned to either a VR condition or a traditional presentation condition. In the VR condition, participants navigated a 3D crime scene simulation freely, while those in the traditional condition viewed 2D crime scene images and videos. Results revealed that VR participants exhibited significantly better memory of the crime scene, felt more confident in their judgments, and perceived a better understanding of the events. The authors argue that VR's integration into legal settings could enhance jury verdict accuracy and reliability by offering a more engaging representation of crime scenes. Although the study acknowledges limitations, such as a small sample size, it underscores VR's potential to create immersive simulations, thereby improving memory and decision-making in legal proceedings.²⁶

In their 2023 paper, Acampora et al. present a mixed-reality game designed to train police officers in tagging evidence at crime scenes. The

game combines virtual and augmented reality, creating an immersive environment where users tag items like weapons, fingerprints, and bloodstains. Using headsets and hand controllers, officers interact with the scene and receive guidance from a virtual mentor. A study with 20 police officers compared the game to traditional classroom training. Results showed that those using the game performed better in tagging accuracy and speed. The authors conclude that this game is an effective and engaging training tool and suggest exploring its use in other areas of forensic investigation.²⁷

Sevcik *et al.* (2022) studied how virtual reality (VR) can improve crime scene testimony. They compared two groups - one viewed a crime scene in VR, while the other saw traditional photographs. Participants then gave testimony in a mock court, and the VR group provided more accurate and detailed responses. The study involved 20 legal professionals and students who either used VR or viewed 2D/3D scenes. VR was found to improve understanding of the crime scene and made the experience more engaging, though a few participants felt motion sickness. The researchers concluded that VR has strong potential in legal settings but stressed the need for further research to address ethical and technical challenges.²⁸

OBJECTIVE OF THE STUDY

The objectives of this research work are summarized below:

1. To document, collect and preserve the evidences from a simulated crime scene using Augmented Reality, Virtual Reality and Synthetic Reality and to apply the same on an actual crime scene.
2. To create and introduce a database of digitally documented, collected and preserved evidences and crime scene as their permanent record which may also be used in the further investigation during a trial in the court of by Law Enforcement Agencies (LEAs).
3. To develop an environment which may be used for the purpose of Crime Scene Reconstruction by the Law Enforcement Agencies during an investigation.

MATERIAL AND METHODS

Materials

- **Collection of Samples:** This study collected samples from 10 different simulated crime scenes and 20 standard samples from real crime scenes from public domains and databases (internet). The samples were photographed and video-graphed, covering all possible angles of capturing the scene of crime. The collected samples were used to create a database, covering various types of simulated crime scenes such as fall from height, stabbing, explosion, suicide, dowry death, hanging, and exhumation.
- **Inclusion and Exclusion Criteria:** In this research study, the author utilized publicly available photographs sourced from the internet and, therefore, chose not to apply specific inclusion or exclusion criteria for standard sample selection. The photographs included were from cases where at least some images were accessible online and served as representative samples for the study.
- **Equipment used for Photography and Videography:** The study used a Motorola g73 mobile phone for capturing samples, utilizing its high-quality camera with a resolution of up to 64 MP and 4K resolution. The phone also features Phase Detection Autofocus (PDAF) and a LED flash for low light photography. Video recording capabilities of up to 1080p at 30 fps were also available. The phone's features, including optical image stabilization, autofocus, and LED flash, ensured clear and detailed images and videos. The images and videos were analyzed for accurate data interpretation.
- **Samples:** The samples were divided and collected in two categories:
 - **Controlled Samples:** For controlled samples, there were different crime scenes simulated; which include the different type of crime scene types like fall from height, stabbing, explosion crime scenes, suicide crime scene, dowry death, hanging and exhumation etc.
 - **Standard Samples:** The standard samples were collected from the public domains or the public database on internet. The images of some well-known crimes were collected for this study, these cases include The Nithari Serial Killing Case, Jessica Lal Murder Case, Telangana Encounter Case, Burari Death Case, Arushi Talwar Murder Case (The 2008 Noida double murder case) and Sushant Singh Rajput Death Case etc.
- **Preservation of samples:** The collected samples were preserved in the HP laptop's internal storage media (Hard Disk) along with their respective unique serial number. A database of these samples was also created in the same system.
- **Tools/Software/Integrated Development Environments used:** There are a number of tools and software used during this project. These tools are: Unity, Paint 3D and 3D Viewer, Stroom, XM Reality, Kontent.ai, ARetize 3D, AR Core, Video Recorder/Camera, Unreal Engine, and Visual Studio Code etc.
- **Ethical Clearance:** This research article does not involve any ethical issues. A informed consent was taken from the volunteers for their involvement in the preparation of the simulated crime scenes during this study. On the other hand, publicly available (from internet) photographs of the real crime scenes were taken as a reference for this study.

METHODOLOGY

A place was firstly identified to make the simulated crime scene in a controlled environment to collect the samples from various type of crime scenes for the effective documentation of the crime scene for the purpose of this study.

At Galgotias University campus, various crime scenes were constructed, documented through photography and videography, and cataloged in a database with Unique Identification Numbers. A total of 154 controlled samples and 20 standard samples were preserved for analysis. These samples underwent processing using Augmented Reality, Virtual Reality, and Mixed Reality tools like Unity, Unreal Engine, Paint 3D, and 3D Viewer. Examination focused on

pixel analysis, preprocessing, pose, surface reconstruction, and texture mapping to document and reconstruct the crime scenes effectively. Sampling methods included purposive sampling, selecting participants or crime scenes based on specific characteristics, and probability sampling, ensuring representation of the broader population. This comprehensive approach aimed to facilitate the documentation, preservation, and reconstruction of crime scenes using advanced reality technologies for enhanced forensic analysis and investigative procedures.

Working of AR & VR

To create an augmented reality experience, you need a camera-equipped device (smart glasses, tablet, or smartphone) with AR software installed. Upon detecting an object with the device, the programme employs computer

vision technologies to examine the video feed and recognize it.⁶

The gadget accesses object data from the cloud, akin to a web browser loading a URL page. Unlike conventional 2D screens, augmented reality (AR) presents this information as a 3D “experience” layered onto the object, merging the real and digital worlds. Users interact with objects via touch, speech, or gestures, accessing real-time data through AR. For example, a user might speak or tap commands within an AR interface to control a product remotely. In industrial settings, operators wearing AR headsets receive performance data overlays and control access for machinery. AR seamlessly integrates digital information with the physical environment, enabling intuitive interaction and real-time data visualization for enhanced user experiences and productivity.^{29,30}

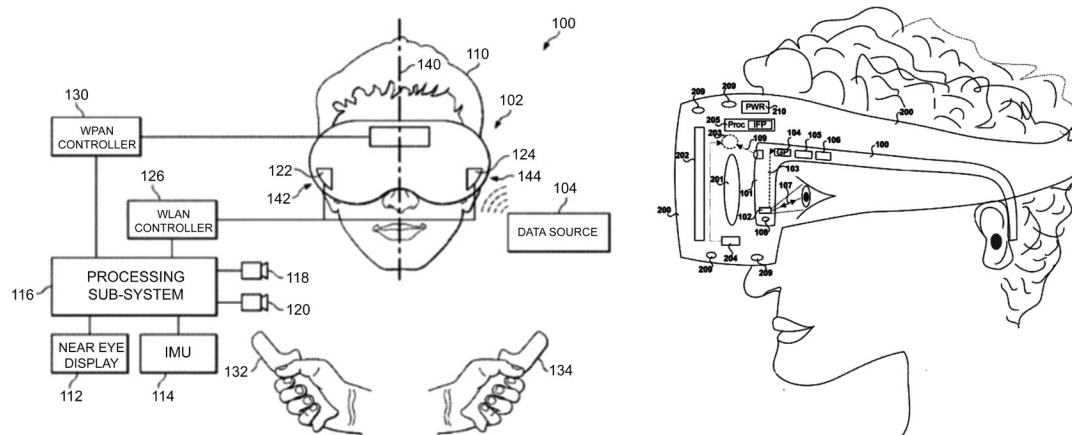


Figure 1: AR and VR Headset

The size and angle of the AR display dynamically change to fit the changing context as the user moves. While older information fades out of view, new graphic or textual information appears. Users in various jobs, such as a machine operator and a maintenance technician, can look at the same object in industrial settings and receive various augmented reality experiences that are catered to their needs.³¹

The link between a smart object and AR is a cloud-based 3D digital model known as an object’s “digital twin”. To create this model, either computer-aided design, often used in product creation, or technology that digitizes things from the real world is used. In order to reflect the current reality of the product, the

twin collects data from the product, business systems and external sources. It serves as a means by which AR software accurately measures and places current information on an object.^{8,10}

Since the technology is still relatively new, it is possible that all forensic scientists won’t be using VR simulations until well beyond 2018. Virtual reality has previously been used as a form of forensic evidence by some persons. A shooting scene was faithfully recreated using the Oculus Rift, according to a New Scientist story on forensic experts from the University of Zurich. This work was later confirmed by law enforcement. Being able to fully immerse yourself in a recreation of the crime scene in this case would help the jury use more of their

senses to reach a verdict. Since virtual reality is only a simulation, forensics experts would also have the freedom to change the scene as they

see fit and remove any objects or images that may not be relevant or that viewers might find objectionable.^{10,32}

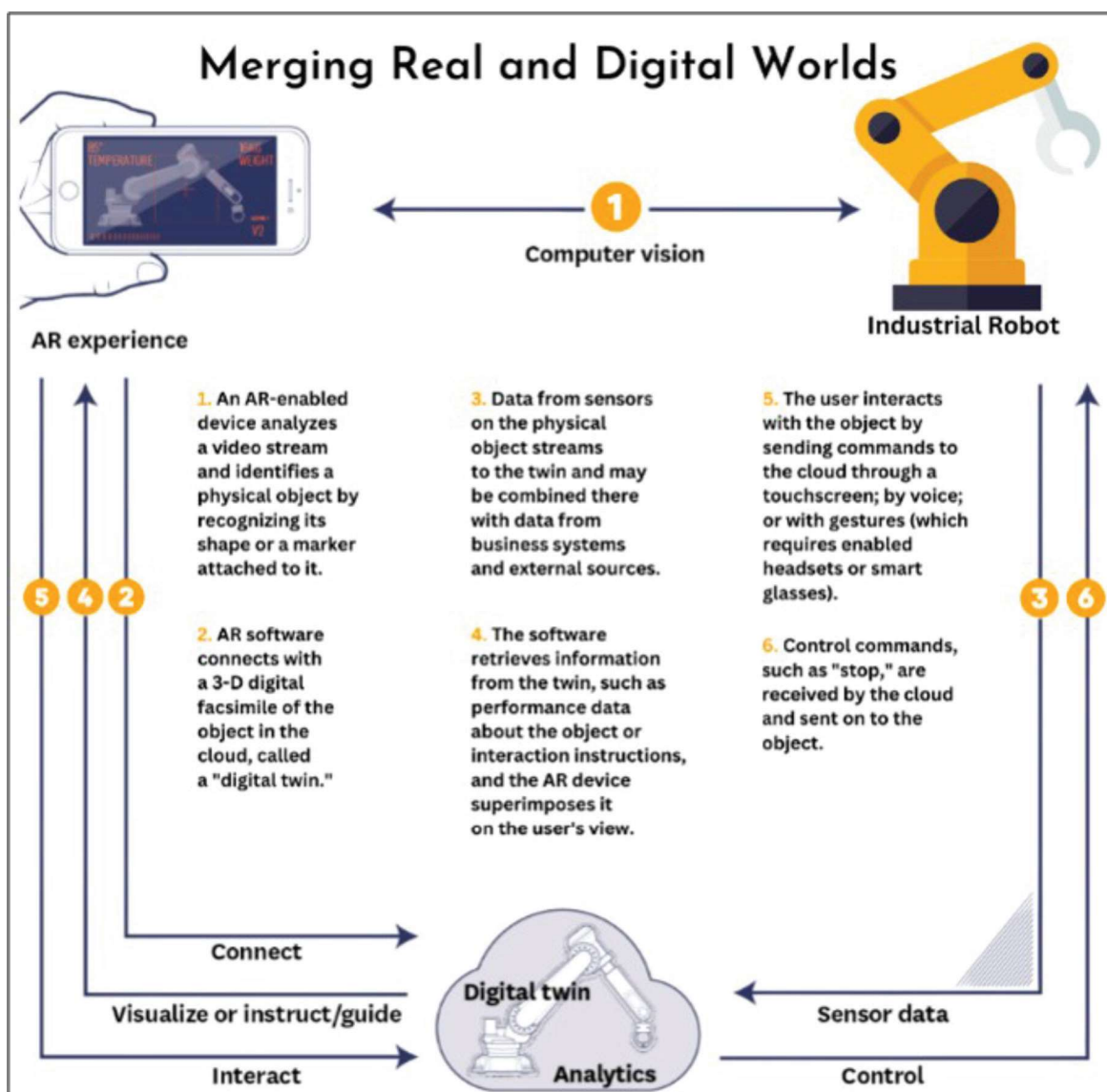


Figure 2: Working of AR and VR

Virtual reality has, of course, a lot more legal use than simply that. In the future, this technology will undoubtedly be used as additional evidence in a variety of ways.

RESULT

General Steps Involved In 3d Crime Scene Reconstruction

Reconstructing a 3D crime scene from photos was a complex task that requires specialized knowledge in computer vision and computer graphics. Below we provided you with a basic

outline of the steps involved, implementing a complete and accurate 3D crime scene reconstruction from photos would require significant expertise in these fields.

Following is an outline of the general steps involved in a 3D crime scene reconstruction from photos:

1. Image Acquisition
2. Image Preprocessing
3. Feature Extraction
4. Image Matching

5. Camera Pose Estimation
6. 3D Point Cloud Generation
7. Surface Reconstruction
8. Texture Mapping
9. Visualization

Implementing a complete and accurate 3D crime scene reconstruction from photos was indeed a challenging task that requires extensive knowledge in computer vision, computer graphics, and image processing. It also requires specialized software libraries, hardware, and computing resources. Additionally, it's important to consider ethical and legal implications when dealing with crime scene data, such as privacy concerns and chain of custody requirements.

Crime Scene Documentation and Preservation Using AR, VR, SR and 3d Processing

Samples from Crime Scene Number 01:

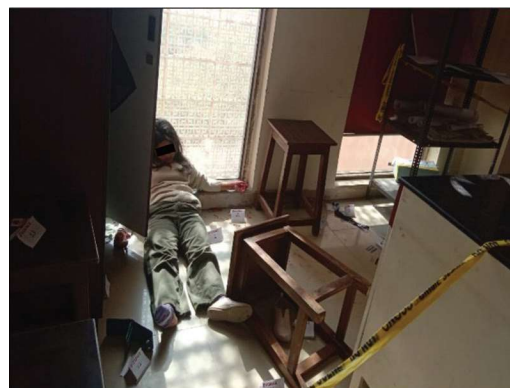


Figure 3: Normal Photograph of Crime Scene 01

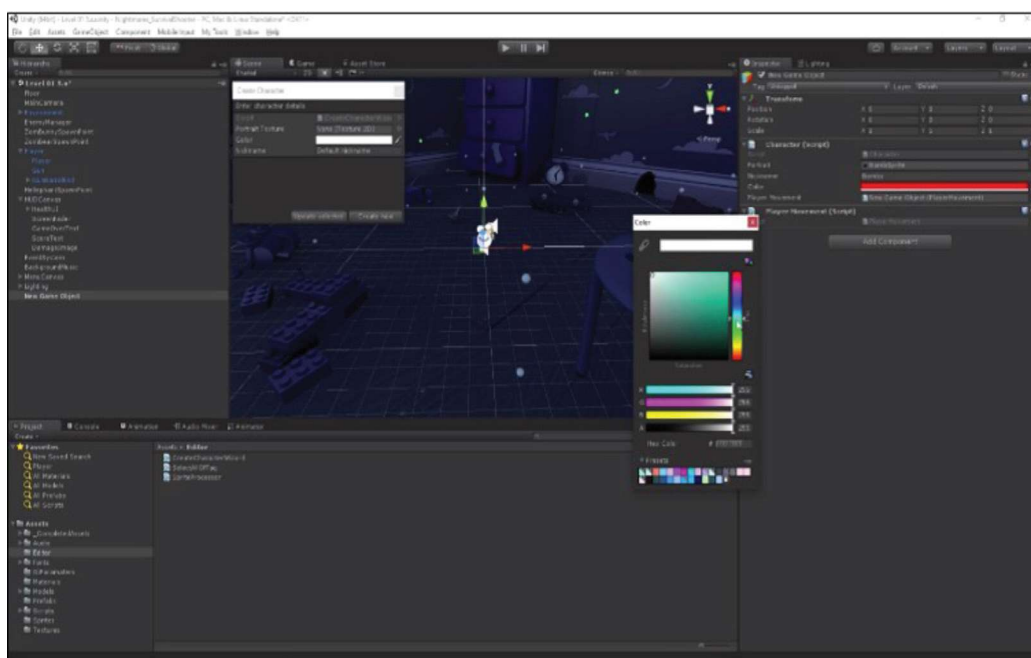


Figure 4: Processed Photograph of Crime Scene 01 in Unity Tool

Samples from Crime Scene Number 02:

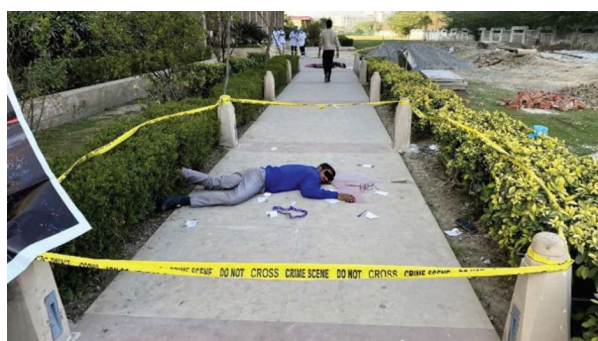


Figure 5: Photograph 01 of Crime Scene 02



Figure 6: Photograph 02 of Crime Scene 02



Figure 7: Photograph 03 of Crime Scene 02

3D Processed Images for AR and VR (Crime Scene Number 02):

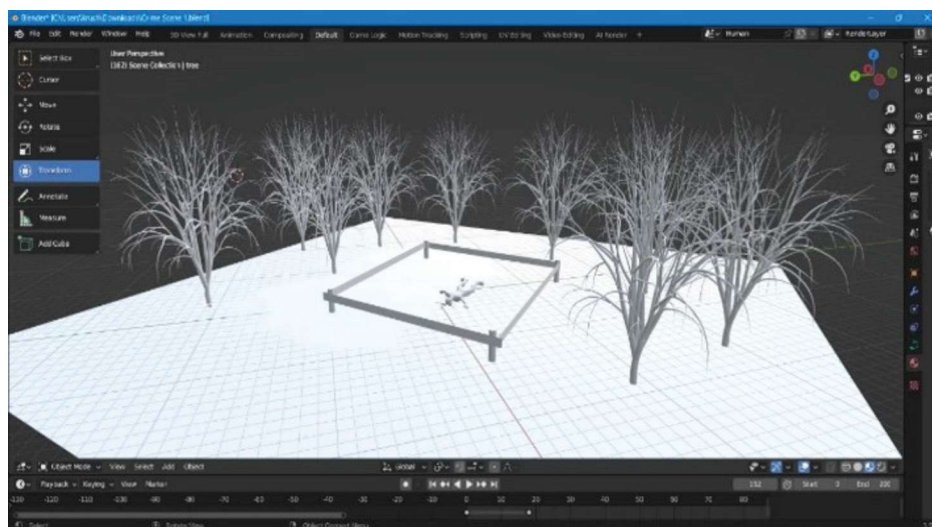


Figure 8: 3D Processed Image for AR & VR - Facing West View

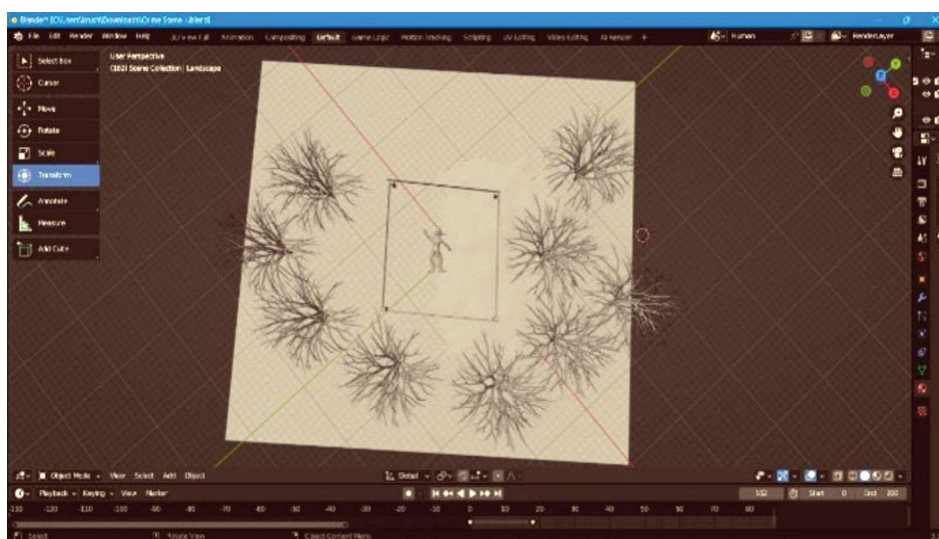


Figure 9: 3D Processed Image for AR & VR -Top View

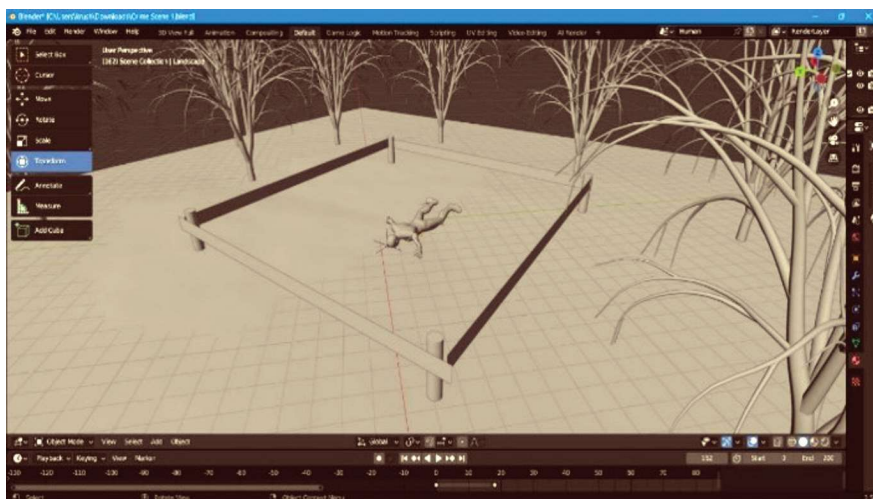


Figure 10: 3D Processed Image for AR & VR Facing South West View

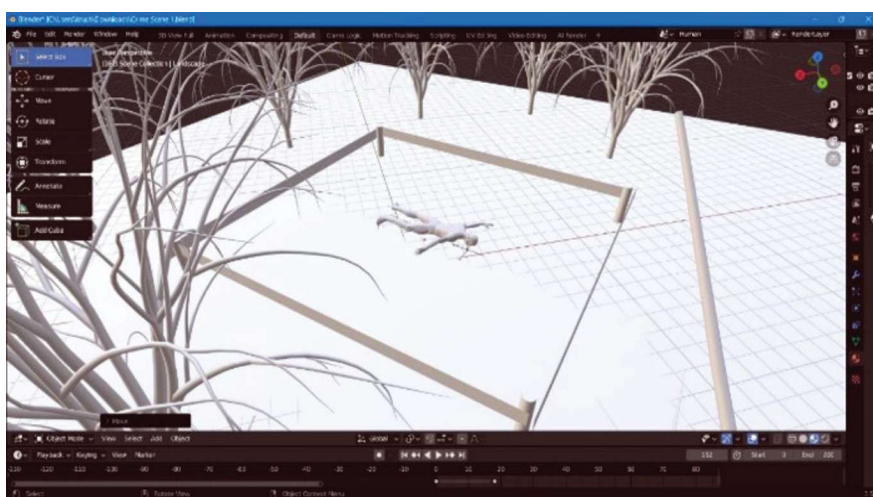


Figure 11: 3D Processed Image for AR & VR - Facing North West View Facing North West View

Constructed Images of some Evidence Found at Different Crime Scenes:

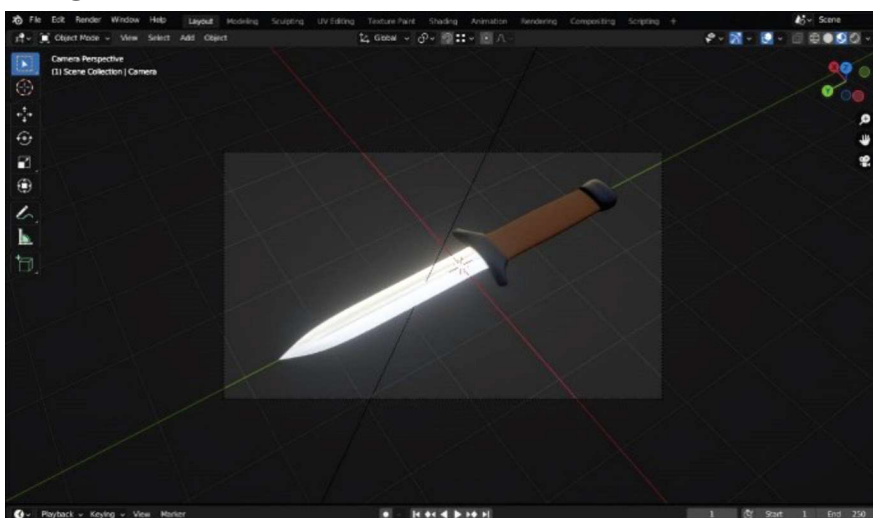


Figure 12: 3D Image of Evidence - Knife

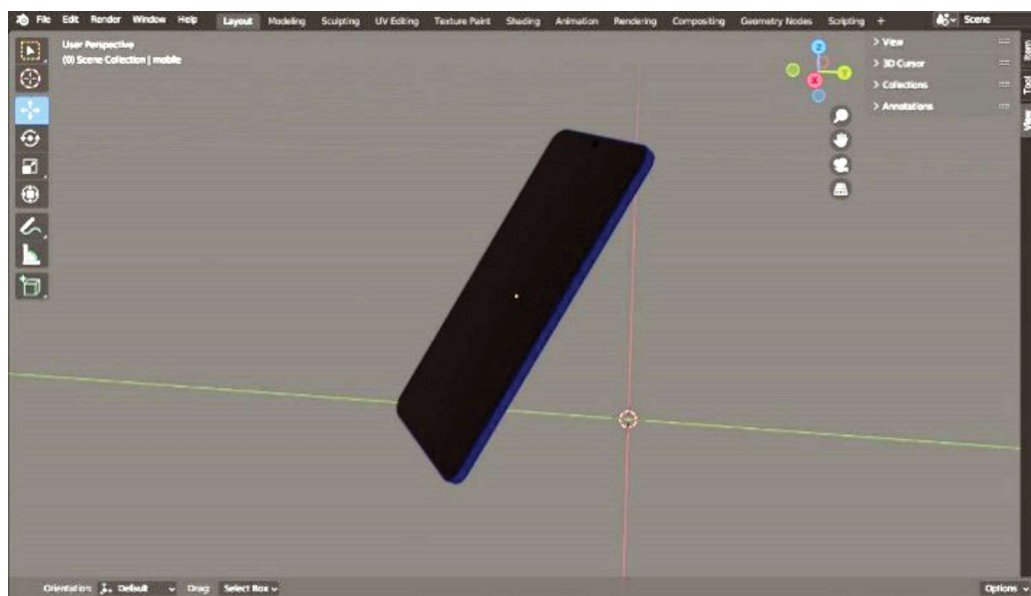


Figure 13: 3D Image of Evidence - Mobile Phone Front View

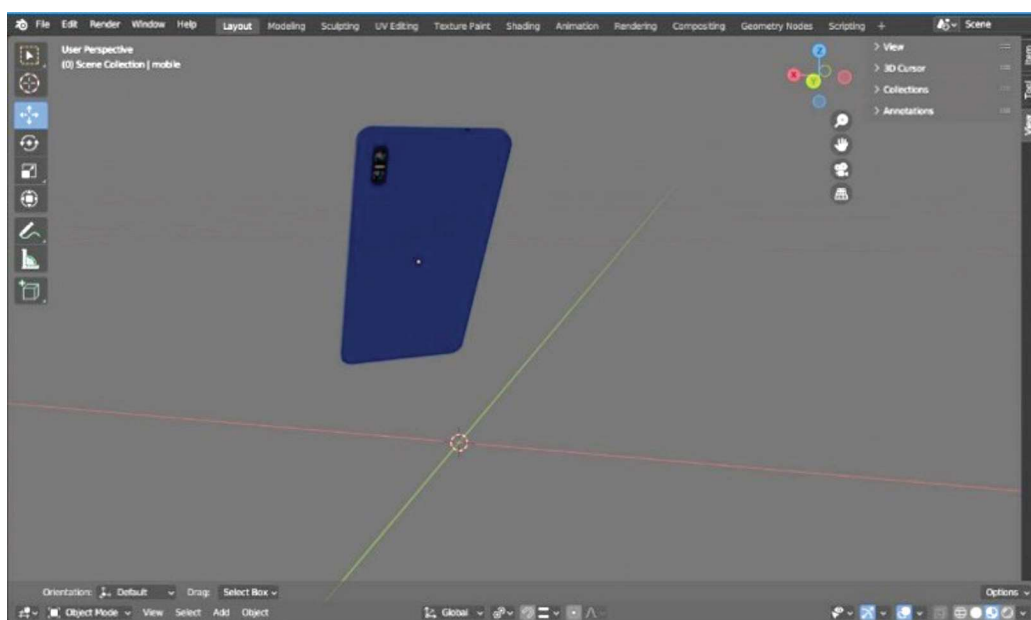


Figure 14: 3D Image of Evidence - Mobile Phone Back View

DISCUSSION

The potential applications of virtual and augmented reality (AR), virtual reality (VR), and synthetic reality (SR) technologies for crime scene preservation, reconstruction, and documentation are examined in this research paper. A mixed-methods approach was used in the research design, combining quantitative and qualitative data. Participants were chosen by purposeful sampling in accordance with their background and level of forensic investigation competence.

The results demonstrated how much the accuracy and effectiveness of crime scene documentation and reconstruction may be enhanced by AR, VR, and SR technologies. By superimposing digital data on the actual crime scene, augmented reality (AR) enables detectives to quickly identify and record crucial evidence. SR provides 3D models for precise reconstruction and analysis, while VR creates a virtual crime scene that can be visited and examined numerous times. A mixed-methods research methodology was

employed in the study, which included expert interviews, surveys, and a case study of a mock crime scene. The results show that the documentation and preservation of evidence at a crime scene can be greatly enhanced by AR, VR, and SR technologies. Additionally, they can aid in lowering the dangers connected to conventional crime scene investigations, such as contaminating or demolishing crime scenes, which could jeopardize the reliability of the evidence.

The study found a number of difficulties and restrictions related to these technologies' application in forensic science. The system is still in its early stages of research, there may be a hardware and software investment involved, and it isn't appropriate for all kinds of crime scenes, such as outdoor scenarios with shifting weather. Furthermore, some firms may find the expense of software and equipment to be exorbitant, and training investigators can be costly and time-consuming.

Lighting, camera quality, and the correctness of 3D models are some of the aspects that affect the accuracy and dependability of AR, VR, and SR technologies. Even though these technologies have the potential to greatly increase the precision and effectiveness of crime scene investigation, more study is required to resolve these issues and investigate how they might be used in other forensic investigation domains.

CONCLUSION

Forensic scientists and law enforcement agencies in India face challenges in documenting and preserving crime scenes due to inadequate training, workload pressure, interference from unauthorized persons, and lack of standard operating procedures. Insufficient training can lead to improper documentation, compromising evidence integrity. The pressure of workload can result in overwork and limited time, resulting in incomplete or inadequate documentation. Lack of standard operating procedures can lead to inconsistent documentation, resulting in errors or inconsistencies in evidence. Court of law challenges include loss of memory, deterioration of physical evidence, and inability to reproduce original conditions.

This research study proposes an innovative method for documenting and preserving

evidence at crime scenes using augmented reality, virtual reality, and synthetic reality technologies. The aim is to improve the effectiveness and accuracy of crime scene investigations while enhancing the safety and training of law enforcement personnel. The study explores the current state of technology and its application in forensic investigation, using a mixed-methods approach for qualitative and quantitative data collection and analysis.

This research study aimed to achieve three main objectives, with some successfully achieved and others partially achieved.

1. The study utilized Augmented Reality, Virtual Reality, and Synthetic Reality to record, gather, and preserve evidence from simulated crime scenes. Using tools like Unity, Blender, and Unreal Engine, samples were taken from various crime scenes. The results exceeded expectations, proving that these technologies can effectively aid in crime scene documentation, preservation, and reconstruction.
2. The study aimed to create a permanent record of digitally recorded evidence and crime scene photos for Law Enforcement Agencies (LEAs) to use during court trials. The **"Crime Scene DPR System"** database contains 154 controlled samples from ten simulated crime scenes and 20 standard samples from public platforms and the internet. The database is associated with well-known cases like the Nithari Case, Burari Death Case, Sushant Singh Rajput Death Case, and Arushi Talwar Murder Case.
3. We are currently in the process of developing an environment that law enforcement agencies can use for Crime Scene Reconstruction during an investigation, which was the third goal of this research. We anticipate that this specific goal will be met in the upcoming research. We did create a Python programme in Visual Studio Code, but it isn't operating very effectively yet. We are making every effort to ensure that it operates effectively, and once it does, we will introduce this system in the interest of forensic science's future.

The integration of AR, VR, and SR technologies in crime scene investigation can significantly

enhance documentation and preservation of evidence. These technologies provide a more accurate and detailed representation of the scene, aiding in the investigation process and increasing the chances of solving cases. They also offer a safer and more efficient means of training law enforcement personnel, leading to better outcomes and reduced injury risk. However, challenges such as compatibility, cost, and accessibility must be addressed. Ethical considerations like potential bias and privacy concerns must also be considered. The study suggests that AR, VR, and SR technologies are promising avenues for future research, but further research is needed to address these challenges and ethical considerations. This research aims to inspire further investigation into emerging technologies in forensic science, leading to improved crime investigation and solving methods.

Limitations and Advantages of AR & VR

Advantages:

- A Crime Scene can be documented and preserved effectively for further use.
- An interactive and virtual walkthrough of a crime scene may be given to the jury during a trial in the court of law.
- Exact location of a crime scene, condition of evidences, types/category of evidences, dimensions and measurements of evidences and other relevant things etc. can be easily documented in the AR & VR environment.
- When done right, VR can be a thrilling sensory experience. Money and creativity are the only constraints when using computer-generated imagery (CGI) to construct alternate universes or present goods or areas in unique and entertaining ways. The Star Trek holodeck's closest equivalent is virtual reality, which will continue to advance quickly in the next years.
- When implemented correctly, augmented reality (AR) can add interesting and helpful information to a real-world situation.
- Simple augmented reality apps for smartphones are well-established.

Limitations:

- AR headsets are expensive and currently available models have numerous severe

flaws. Both feature a small selection of fields, and using the gesture controls can be challenging. Till the costs are significantly reduced and the form factor is enhanced, we won't see mainstream customer use.

- The near future will see AR headsets limited to specific applications and away from general use due to their nerdy aesthetic.

Future Scope

Virtual and augmented reality (VR/AR) technologies have rapidly evolved from science fiction to practical applications in various sectors such as transportation, education, and entertainment, revolutionizing how industries achieve their goals. While VR offers powerful tools to broaden perspectives and facilitate more accurate judgments in various contexts, including forensics, it's unlikely to completely replace traditional methods and may not be universally applicable. Nonetheless, forensic researchers are exploring its potential applications in courtroom settings. AR, on the other hand, presents opportunities for law enforcement officers to enhance situational awareness and response capabilities by breaking the "reaction to action" cycle, enabling quicker responses to developing events and potentially denying adversaries the initiative. Ultimately, VR/AR technologies hold promise for improving communication among forensic experts and recreating crime scenes for witnesses, offering valuable tools in the field of forensic science.

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