IJARST

International Journal of Advanced Research in Science and Technology

https://doi.org/10.62226/ijarst20262684

ISSN 2319 – 1783 (Print)
ISSN 2320 – 1126 (Online)

Virtual Reality and Augmented Reality in Forensic Training

Rovikono Naleo[1], Miss Charu Saklani[2]

[1]M.Sc. Forensic Science, School of Applied and Life Sciences (SALS), Uttaranchal University, Dehradun, India

[2]Assistant Professor, School of Applied & Life Sciences (SALS), Uttaranchal University, Dehradun, India

rovikononaleo@gmail.com

ARTICLEINFO

Article history:

Received 06 May 2026
Accepted 18 May 2026
Available online 29 May 2026

Keywords:

Virtual Reality (VR), Augmented Reality (AR), Forensic Science Training, Crime Scene Investigation, Immersive Learning Technologies, Forensic Education and Simulation

Indexed in:

and in major libraries

ABSTRACT

Forensic experts are crucial for solving crimes as they examine crime scenes and collect evidence. But outdoor crime scenes, can be contaminated easily by weather conditions, animal movement, or human activities so valuable clues will get destroyed making the investigation complicated. Virtual Reality (VR) and Augmented Reality (AR) have gained attention in the field of forensic science. VR enables users to step into a digital world and experience 3D environment and AR adds holograms or digital data into the user's physical world. These tools were initially used to measure distances of objects at a crime scene. But now, VR and AR are being used for training forensic experts. Instead of only conventional practice, students and investigators can experience realistic crime scenes, and interact with the virtual world which improves the safety of the students. This kind of virtual training is also cost-effective and more convenient as mistakes made can be corrected without real consequences, which develops confidence and skills and allowing trainees to experience a various crime scene that is difficult to recreate in real life. These technologies will grow in importance and may even be used in actual investigations or courtroom presentation to help explain crime scenes in a less complex way. In this review, we explore how VR and AR are opening new possibilities for training forensic professionals putting together traditional methods with innovation to create more effective, practical experiences and the future scope of VR and AR in forensic fields.

INTRODUCTION

Careful analysis of a crime scene is one of the most critical steps in any forensic investigation. The primary goal is to gather and examine evidence that could establish who is responsible for the crime. However, this process is not without its challenges. According to several research and studies it has been found that the judgement of a forensic expert can sometimes be influenced by their own psychology and emotional aspects, leading to affecting the decisions they make during investigations. Moreover, there is intense pressure to secure and collect the evidence as quick as possible as it is difficult to preserve the original conditions of the crime scene, adding to the risk of lost evidence or contaminating the scene or traces. When the interpretations are not clear and there is a lack of supporting evidence, it can negatively impact the outcome of a case and eventually lead to wrongful convictions.

Now in this modern generation Virtual Reality (VR) and Augmented Reality (AR) are starting to bring a new approach to the way forensic experts deal with crime scene investigations. Since the beginning of the forensic science era, preserving the state of a crime scene in its original form has always been the biggest challenges a forensic expert must deal with. It can be the weather, animal, or human activities, and even physical or emotional pressure during an investigation which leads to the loss or contamination of evidence. Critical thinking and quick decision making are required, but this can also open opportunities for mistakes that could impact the case.

VR and AR contribute new ways to investigate, analyse, secure, and protect the crime scenes without risk. VR enables the users to step inside a fully recreated and virtual, 3D version of a crime scene, granting them the freedom to explore all types of details and evidences without disturbing anything physically. Moreover, AR brings the computerised data or information directly into the physical world, helping the forensic teams visualize connections between evidence in real time.

Not only for the preservation of crime scenes, but VR and AR are making a real difference in how forensic experts are trained. Instead of only theoretical reading of case studies or practicing on fake crime scenes, trainees can now experience realistic scenarios, handle virtual evidence, and even if mistakes are made, they could learn from it cause the actual crime scene is not destroyed thus building up confidence in their skills. Immersive virtual laboratories created by

Guarnera *et al.* [7], which were designed for ballistic analysis, give the users hands-on experience with complex tools and techniques, but in a safe and repeatable digital environment.

According to the paper written by Carew *et al.* [16] digitalised technologies can increase the accuracy and strengthened the reconstruction of many used crime scenes. These technologies provide opportunities for more advanced analysis. The collection of data from VR and AR environments, especially 3D point clouds, is used for training AI models to recognize patterns or match pieces of evidence that if done by humans will take a much longer time.

This review paper, discuss on the aspects of new and innovative use of VR and AR in forensic training. Users get to interact with objects in a virtual space and bringing the 3D information into the real world, increasing safety for the students and reducing risk of making crucial mistakes being more cost effective at the same time.

At the core of using VR and AR in forensic science is not about using the technology but it is about making investigations more accurate, safer, and better for the forensic experts using it. These tools are making a future where forensic experts can work smarter, train better, and ultimately bring stronger evidence to the pursuit of justice in the court of law.

Virtual Reality (VR):

Virtual reality (VR) technology enables the users to enter a fully virtual environment using specialized equipment such as gloves or headsets or a closed space, virtual reality (VR) creates an illusion for the users making them feel like they are at another location, a game, a crime scene, or even space. The 3D environment created can also allow users to move around, interact with items, and experience things nearly as they would in real life rather than only staring at a screen.

VR was first introduced as part of the "virtuality continuum" model by P. Milgram *et al.* back in 1994 [14]. From then on, VR has continually developed and expanded, now fitting within the field known as Extended Reality (XR), which also includes technologies like Augmented Reality (AR) and Mixed Reality (MR). Immersive VR is designed to create a strong sense of presence to the virtual world, which is achieved through devices like the head-mounted displays (HMDs) or immersive environments like CAVE (Cave Automatic Virtual Environment) systems where a cube shape room is used for a projection space to experience the virtual environment.

Recently, researchers have been exploring how VR could be helpful and applied to forensic science. Though existing scanning technologies can provide the high precision required in forensic work, the rate of adoption of immersive technologies remains low. According to the paper written by Maneli *et al.* [12], there is a general lack of trust in immersive technologies continues to slow their widespread use. However, there are growing availability of affordable, high-quality VR devices that has shown to be cost-effective and collaborated with forensic science. These immersive technology reconstructions enhance the perception of space and location within a crime scene including the combination of original photographs and reference information increases the reliability of the data shared between investigators.

An example is of the virtual forensic ballistic laboratory developed by Guarnera *et al.* [7], where forensic experts used VR technology to handle 3D cartridge cases and bullets. Having the ability to freely manipulate point cloud models in a virtual environment led to more accurate ballistic comparisons, proving that there is improvement over the limitations of traditional optical comparison microscopes.

Augmented Reality (AR):

Augmented Reality (AR) is a technology that combines digital content like images, information, or 3D objects with the real environment. AR does not take the users into a completely different settings like Virtual Reality (VR) instead it adds virtual elements to the actual surroundings, so that users can see and interact with both at the same time. The use of special glasses, a phone, or even a tablet is required to experience it.

Augmented Reality (AR) is an intriguing link between our virtual and real worlds, allowing users to interact with both simultaneously (Lee, 2012) [9]. Unlike Virtual Reality (VR), which completely immerses you in a digital environment, AR enriches our daily experiences by layering in additional elements—such as graphics, sounds, videos, or GPS data. These days, if you want to dive into the world of augmented reality (AR), the best way to do it is through smartphone apps that blend GPS data with some cool visual effects. Unlike virtual reality (VR), which often demands expensive headsets connected to powerful computers, AR usually works on devices we already own, like our smartphones or tablets (Wasko, 2013) [17]. While high-quality VR headsets can cost anywhere from $400 to $3,000 (Lamkin, 2017) [8], smartphones are much more budget-friendly, and a lot of AR apps are free to download.

A fantastic example of AR hitting the mainstream is the mobile game Pokémon Go which was a game released in July 2016 by Niantic, this game took the world by storm, seamlessly combining GPS technology with interactive graphics and just within two weeks after its launch, it racked up over 100 million downloads (Doran & Davis, 2016; Moon, 2016; O'Rourke, 2016) [2]. The phenomenal success of apps like Pokémon Go shows that augmented reality is not just a passing fad it is a groundbreaking technology that has the power to change the way we interact with the world around us.

REVIEW OF LITERATURE

According to the study conducted by Antonino Zappala *et al.* [19], they developed a system that used VR and deep learning to enhance the investigation in a crime scene. They first created a 3D model of an indoor crime scene using photogrammetry, which is a process of taking over 1000 high-resolution photographs with special equipment's and developing them into a 3D model. This model was then imported into a VR application built using Unity and

deployed on a Meta Quest 2 headset. In the VR environment, users could walk around, manipulate objects, measure distances, and interact with the scene using controllers. To assist forensic analysis, the system integrated a server that ran deep learning algorithms, mainly Faster-RCNN, to automatically detect and label objects like weapons or personal items within the virtual scene. Users could highlight parts of the scene they were interested in, send snapshots to the server, and get real-time identification of evidence objects. Several deep learning models (SSD, YOLOv8, YOLOv9, and Faster-RCNN) were tested, and Faster-RCNN achieved the best performance in object detection, despite being slower than others. A log book about the user actions was also recorded to ensure that the pattern of the analysis can be repeated. The result of the project showed that combining VR and AI in forensic can make the crime scene investigations safer, increase accuracy and less contamination for the experts, with the future aspect to aim at the methods to detect difficult forensic traces like blood patterns and fire damage.

In this paper written by Andrew P. Gee *et al.* [1], the authors developed a system that uses Augmented Reality (AR) to assist forensic investigators during crime scene investigations. The system allows investigators to virtually annotate real-world environments by combining GPS, Ultra-Wide Band (UWB) positioning, and visual SLAM (Simultaneous Localization and Mapping) technology. Field operatives are equipped with wearable computing devices like a camera, GPS/UWB sensors, and a touchscreen to move through the crime scene and build a shared virtual incident map in real-time. Using AR, investigators can mark important objects, annotate evidence, and add structural information like walls, doors, and windows into the virtual map, all while remaining in the physical environment. the annotations of AR are geographically accurate, allowing the evidence to be viewed exactly where it was found, so even if the original objects are to be removed later it can still be viewed in the same place using AR technology. This system helps in the improvement between multiple investigators or experts by allowing them to see and share remarks instantly using a wireless network and a central control centre. Thus, AR makes it easier and faster for crime scene documentation, keeping it more organized, and providing investigators with a richer, geographically accurate view of the scene and can be also used for future analysis as well.

Holly Vanessa Wilkins *et al.* [3], this paper emphasizes how Virtual Reality (VR) and Augmented Reality (AR) technologies helps in re-structuring crime scene investigation (CSI) in training and education. Traditional and conventional training method relies on physical crime scene facilities, but turns out that these are expensive, it is not flexible, and is difficult to access especially during pandemic example COVID-19. Virtual tools like VR have already been used to simulate entire environments where students can make decisions, but VR mainly focuses on cognitive (decision-making) skills and does not fully support hands-on physical skills.
Augmented Reality (AR), however, offers a new layer of possibilities by blending virtual objects like holographic evidence markers and crime scene elements into the real world. AR allows the users to be aware of their actual surroundings even while interacting with the virtual settings, enabling both decision-making and psychomotor skills to be possible at the same time (i.e., dusting for fingerprints or taking real photographs). This makes AR can bridge the gap where full physical crime scenes are not possible making it an asset in terms of forensic training. This research also explains that the AR technology can be accessed through headsets like the Microsoft HoloLens 2 or even mobile devices. These devices enable the trainees to build their own custom holographic crime scenes anywhere they want, even in an empty room which offers flexibility, is cost effective, and is easy access to a wider variety of training scenarios. AR contributes to collaborating, exchanging of feedback in real time, and teamwork, making it easier for the facilitators to monitor the students remotely, provide direct instruction or even helps with assessing and evaluating the performance of trainees based on the recorded actions. While AR cannot entirely replace physical crime scene simulations, it adds a powerful new tool for re-training, remote learning, and simulating dangerous scenes (like clandestine labs or hazardous environments) safely. In conclusion, AR could help improve student engagement, retain useful information, and ensuring the safety of the students, making crime scene training more accessible, cost effective and modernized. However, it also focuses on the need for further research, validation, and careful planning before AR can be fully integrated into standard forensic education programs.

According to the research conducted by Walid M Khalilia *et al.* [18], this study helps in exploring how Virtual Reality (VR) supports the training of forensic science students by offering an alternative option to traditional crime scenarios. Considering the high costs and limited resources of physical mock crime scenes, researchers at Al-Istiqlal University has developed a new VR platform through the TESLA project to help students to engage with realistic crime scenes in a digital space. Through VR headsets, students could move around virtual environments, investigate simulated evidence, and practice key forensic tasks such as securing the scene, identifying evidence types, estimating time of death, and simulating DNA collection.
The virtual system was built using Open Simulator software and included interactive 3D models that replicated crime scene conditions. The students used virtual tools, like digital cameras and measurement devices, to carry out various forensic procedures at the same time responding to various tasks which helps them sharpen their problem-solving, critical thinking and decision-making skills. Activities that involve collaborative work were highly encouraged, allowing multiple students to work together and discuss findings within the virtual scene.

The feedback from the students resulted to finding out that VR was helpful for improving practical skills and for improving teamwork and critical analysis. The immersive training was especially useful during the times when access to real facilities was restricted, an example would be during the COVID-19 pandemic. In the end, the study shows that VR can make forensic education more flexible, engaging,

and accessible, while maintaining a strong focus on both technical skill-building and cognitive development.

The 2015 research paper by Kilgus, T., Heim, E., Haase, S. *et al.* [6], has introduces a new way to help forensic pathologists during autopsies by using mobile, markerless Augmented Reality (AR). Traditionally, autopsies rely heavily on visible signs, touch, and the experience of the forensic expert. Although CT scans are often available, they are rarely used during autopsy because workstations to view them are missing in many forensic facilities. To overcome this, the researchers had developed a new system where a tablet, equipped with a range camera, captures both the colour and depth information of the body then a server processes this data to align the 3D CT scan with the real body, allowing forensic experts to "see inside" the body in real time via AR which is like having an X-ray vision. The device has helped to project internal injuries, like fractures or organ damage, which was directly projected onto the body during the examination, without needing heavy or complicated equipment or damaging evidence. This system is simple, easy, portable, and relatively low-cost, making it easier to use in daily forensic routines compared to other expensive procedures and technologies. Other than assisting in autopsies, AR visualization can be used for documentation and courtroom presentation to make it easier while explaining to the judge, juries, and non-experts present in the court.

Tests were performed on fake and real human corpses which showed that the system provides sufficient accuracy for practical use, with a mean registration error around 4 mm. While still a prototype, the study demonstrates that AR can significantly enhance how forensic data is visualized and communicated, offering a more intuitive, mobile, and affordable solution for forensic medicine.

The research conducted by Karabiyik *et al.* [5] introduces a Virtual Reality (VR) framework which is designed to train the first responders in a crime scene and digital forensic investigators. Acknowledging the various challenges and high expenditure associated with the traditional and conventional ways of forensic training, the authors have developed a VR-based solution that offers a flexible, and engaging way to teach important investigative skills. The framework is composed of two parts: a training section, where trainees learn different procedures, and an evaluation section, where their performance is assessed based on evidence collection, task sequence, and different task. The framework was built utilizing the Unity3D engine, and this system allows the users to navigate virtual crime scenes, interact with digital objects, and use investigative tools like virtual cameras, evidence bags, notebooks, and rulers. Trainees can perform actions such as tagging and bagging evidence, measuring crime scene elements, and recording findings, closely mimicking real-world forensic tasks. The framework also records performance data, such as whether evidence was missed, if the correct order of operations was followed, and how long the tasks took, offering detailed feedback to both the trainee and supervisor. VR enhances practical knowledge and help trainees develop critical thinking and decision-making skills keeping them in a safe environment. Because the framework is cost efficient by supporting affordable, consumer-grade VR devices, it provides a solution for institutions looking to modernize forensic training. The paper concludes by suggesting that future versions of the framework will include more realistic crime scene variations and adaptive difficulty to better prepare trainees for real-world investigations.

The study performed by M. Albeedan *et al*. [11] investigates how AR and VR can help transform crime scene investigations. It brings out the importance of the growing capabilities of technologies like Microsoft HoloLens to help the forensic experts collect, visualize, and manage evidence more efficiently, considering when time and distance are major challenges. By using 3D representations and advanced positioning systems, forensic investigators can better preserve, analyse, and collaborate on crime scenes, even remotely. The research points out the distinct roles of VR and AR: VR completely immerses the user in a digital environment, ideal for training and reconstruction, while AR enhances the real world by overlaying digital information onto physical surroundings, making it perfect for real-time investigation work. The paper discusses various case studies and past projects where AR and VR have improved teamwork, decision-making, and accuracy in forensic work. Using a mixed-method approach, the researchers developed a prototype AR application through user-cantered design principles. They focused on helping police officers enhance their skills in crime scene management by testing the system with junior investigators from the Kuwait police force. 3D crime scene scanning are features that help with evidence handling, and crime scene reconstruction that can help make investigations faster, safer, and more convenient for collaboration between different sectors. The study concludes that combining AR and VR into forensic practice improves evidence collection/handling and crime scene analysis, opening possibilities for new training, crime scene simulations, and courtroom presentations. Future work will aim to improve system flexibility, predict crime scenarios more accurately, and adapt these technologies to real-world field conditions.

Teaching crime scene investigation skills has always been a crucial part of forensic science education, but running traditional mock crime scenes is often expensive, time-consuming, and limited in variety. To find a more flexible and cost-effective solution, the researchers Richard Mayne and Helen Green created a virtual reality (VR) application specifically designed to simulate crime scenes for training purposes. [15]. The researchers built a fully interactive VR environment using Oculus Quest headsets, where the users have the will to move freely, search for evidence, place evidence markers, and take photographs just like they would in real investigations. Two groups undergraduate forensic science students and forensic science educators tested the system. Participants were judged on their ability to find hidden evidence, correctly document it, build a logical hypothesis, and suggest next steps in an investigation.

Both groups responded positively, saying the VR experience felt immersive and helped improve their investigative skills. Motion sickness was rarely a problem, and users appreciated being able to work independently and practice without real-world limitations. Even though VR cannot completely replace hands-on training, the study showed that it offers a valuable way to supplement forensic science education, giving students more opportunities to practice critical thinking and evidence handling. The researchers found out that initially there will be expensive in setting up the VR systems, but it could save more money as time goes by unlike the conventional methods where it is necessary to maintain the physical yet fake crime scenes. So the conclusion is clear: VR is a practical, engaging tool that can enhance learning, broaden students' experience, and make crime scene training more accessible to a wider range of learners.

The research proposed by Albeedan Meshal [10] focuses on the progress and use of AR technologies to help and improvise crime scenes investigation and documentation, also addressing the disadvantages of traditional crime scene training which includes high costs, limited access, risks of contaminating evidence, and various other challenges. The study proposes an augmented reality (AR) system designed to create a more flexible, realistic, and safer environment. It utilizes devices like the Microsoft HoloLens 2 to build a system that overlays digital information—such as evidence markers and 3D reconstructions—onto the real world. This allows investigators and students to engage with crime scenes without the risk of altering or damaging them. Through detailed 3D scanning and photogrammetry, real crime scenes were virtually reconstructed, giving users the ability to walk through and analyze them using AR headsets. This approach creates an immersive experience while keeping users connected to the real world. It turns the practice of skills like evidence collection, documentation, and scene analysis into something that feels both natural and engaging.

One features of this AR system is its ability to boost collaboration. Multiple investigators can view and interact with the same virtual elements simultaneously, even if they are working remotely. The study also showed that AR improves the accessibility of training, offering opportunities for realistic practice without the heavy resource demands of setting up physical mock crime scenes. Surveys conducted with over 160 police academy students, along with feedback from forensic experts, revealed that users found the AR system to be not only effective but also user-friendly and incredibly beneficial for honing real-world investigative skills. Participants truly appreciated how AR seamlessly combined visual data with hands-on exploration, which deepened their grasp of spatial relationships at crime scenes and enhanced their critical thinking during investigations.

There is a book written by Levstein Ian [4] that focuses on the development of a mobile, markerless Augmented Reality (AR) application called CSI4FS, designed especially for helping in the progress for forensic science education and crime scene investigation (CSI) training. Traditional CSI training usually requires access to physical spaces like mock crime scene houses, which are costly to set up, limited by space, and sometimes difficult to schedule. To solve these issues, the study proposes using AR technology through common devices like smartphones to create virtual crime scenes anywhere, without needing special equipment or permanent installations.

METHODOLOGY

The methods that were used in developing Virtual Reality and augmented Reality in order to help in crime scene investigations as well as with the training of forensic students are listed below:

Use of VR in Enhancing Crime Scene Investigation [19]

Instrumentation used: VR headset, Unity 3D Software (it is a game engine and a real-time 3D development platform created by the Unity Technologies), photogrammetry, Agisoft Metashape Software and Deep learning.

In this method a full virtual crime scene is created using photogrammetry, which is a method where hundreds of high-quality photos are taken with a Sony ILCE-7SM2 mirrorless camera and a Sony 12-24 mm lens. These images are then later processed using Agisoft Metashape software to create a detailed 3D model of the crime scene.

The 3D model was created and then transferred to the Unity3D engine to set up a Virtual Reality (VR) environment. Once that was done, the app was launched on the Meta Quest 2 VR headset. This setup allows students or forensic experts to wear the headset and immerse themselves in the crime scene, where they can explore, examine, and interact with the environment just as they would in real life.

To boost the system's functionality, they connected it to a server that runs deep learning models, like Faster-RCNN. This integration allows the VR app to automatically identify and label important objects, such as weapons or pieces of evidence, right at the scene.

The Cap Stone Project- CSI4FS [4]

Acronym for CSI4FS- Crime Scene Investigation for Forensic Science.

The CSI4FS application was designed with help from experienced forensic investigators who guided the project to make sure it followed real crime scene investigation procedures. They outlined six key steps that crime scene work usually involves: assessing the scene, observing carefully, documenting everything, searching for evidence, collecting it properly, and analysing the information. Their point of view about the case helped to create the app that would feel more realistic and teach essential forensic skills. The app itself was built to give students a hands-on, interactive learning experience. In each virtual scene, users are asked to find clues and think about how those clues help solve a case. To improve the critical thinking and deep observation of the students the app challenges the students by establishing fake clues known as "red herrings" which the students must stop and distinguish between the real and fake clues.

Several self-made data were written to control the phone's camera, track how the user moves, create surfaces where evidence appears, and allow students to interact with virtual objects. The app does not need any physical markers like QR codes; instead, it places evidence in the environment using just the smartphone's camera and sensors.

Once the app was ready, it was tested by publishing it on the Google Play Store, allowing students and trainees to easily download and use it on their phones. Students could then move around real spaces while seeing virtual evidence through their screens, practicing skills like tagging and collecting evidence just as they would at an actual crime scene.

Crime Scene Investigation through AR [10]

Instruments Used: Laser Scanner (to scan the real world), Microsoft Hololens2, checkboard markers recommended by FARO, and FARO scene software

Using augmented reality, the team of developers created a lifelike virtual crime scene, choosing an educational crime scene facility at Winchester University as their scanning spot. They meticulously arranged the scene by positioning mannequins to stand in for victims and added extra lighting to illuminate the darker areas, making sure every detail was captured with clarity. During the scanning phase, they took a total of nine scans from different heights and angles to make sure there were no missing spots. Checkerboard patterns were put up on the walls to make sure all the scans could be lined up and merged accurately later. Once the scanning was complete, the collected data was processed using FARO Scene software, which effortlessly stitched the individual scans into a single, detailed 3D model. In the end, the fully reconstructed crime scene was uploaded to the Microsoft HoloLens2, allowing students and investigators to virtually walk through, explore, and interact with the crime scene as if they were there.

Application Of AR in CSI [3]

Instruments Used: Microsoft Hololens2, Photogrammetry, 3D Holographic designs, Psychomotor

The procedure for using Augmented Reality (AR) in crime scene investigation training began with creating virtual crime scenes through 3D scanning and holographic modelling. These digital crime scenes were then accessed by students using either AR headsets like the Microsoft HoloLens 2 or mobile phones equipped with AR applications. As students navigate through real spaces, they can see and interact with virtual evidence placed all around them. They get to practice tasks like placing evidence markers, measuring distances, snapping photos, and jotting down observations. Throughout the session, facilitators keep an eye on student performance in real-time, offering instant feedback and making corrections when necessary. The whole investigation process is recorded for review and evaluation later on. This approach provides a safer, more flexible, and budget-friendly way for students to dive into various crime scene scenarios, enhancing their decision-making and practical skills in a realistic yet controlled setting.

VR and 3D visualization in Forensic visualization.[13]

The project was all about crafting fully digital 3D environments that really brought crime scenes to life. It allowed users to dive into the scenes from various angles whether they were stepping into the shoes of the victim, the suspect, or a witness. They used Augmented Reality (AR) techniques to superimpose digital elements, like cars and weapons, right onto real-world settings, which could be viewed through transparent glasses or video screens. This mix of the real and virtual worlds made analysing crime scenes feel more intuitive and detailed. With the use of motion tracking, users can move around naturally in the virtual space, while computer vision tech helped turn photos of actual locations into precise 3D models. To make sure that recreated events, like car crashes or body movements, looked realistic, they applied dynamic simulations based on physics. Plus, natural language processing tools were utilized to automatically create basic 3D models from written crime scene reports, using software like CarSim and CONFUCIUS. All these techniques came together to create a more immersive, trustworthy, and scientifically robust way to reconstruct and present forensic evidence.

APPLICATIONS

Crime Scene Investigation Training

VR allows forensic students and investigators to practice analysing crime scenes in a fully immersive 3D environment. They can walk through virtual spaces, identify evidence, mark items, take virtual photographs, and even practice scene measurements all without physically being at a real crime scene. AR further enhances this by allowing trainees to interact with digital evidence placed within real-world environments, helping them maintain situational awareness while still engaging with realistic training scenarios.

Evidence Collection and Documentation Practice

Both VR and AR create opportunities for practicing the proper collection, tagging, and documentation of evidence. Students can simulate critical tasks like maintaining chain of custody, collecting biological samples, photographing scenes, and preserving delicate evidence. In AR settings, virtual markers and digital notes can be added directly onto real-world locations, offering hands-on experience in maintaining accurate forensic records.

Courtroom Demonstrations and Testimony Preparation

VR and AR tools are increasingly being used to help forensic experts prepare for courtroom presentations. Trainees can use virtual reconstructions of crime scenes to practice explaining findings to judges, juries, and legal teams in a way that is easy to understand. Interactive AR models allow users to highlight and interact with evidence during mock trials, helping trainees build strong communication and presentation skills.

Forensic Ballistics and Trajectory Analysis

VR applications are being developed to simulate ballistic evidence analysis, where users can inspect 3D models of

bullets, cartridge cases, and gunshot trajectories. This helps trainees understand complex shooting reconstructions without needing expensive lab equipment. AR overlays can also display bullet paths and impact points within real-world settings during training exercises.

Remote Learning and Virtual Field Trips

VR and AR make it possible for forensic students to experience a variety of crime scenes and forensic labs remotely. Through virtual field trips, students can explore crime scenes from different regions or historical cases without leaving their classrooms. This application became especially valuable during the COVID-19 pandemic, offering an alternative when physical access to labs and training facilities was limited.

Hazardous Scene Simulation

Certain crime scenes, such as those involving chemical, biological, radiological, or nuclear hazards, can be too dangerous to recreate physically. VR and AR provide a safe and controlled way to simulate hazardous environments, allowing trainees to learn appropriate safety protocols and evidence handling techniques without exposing themselves to real risks.

Autopsy and Forensic Medicine Training

AR can be used to enhance forensic pathology training by overlaying digital internal structures onto mannequins or real cadavers. This allows trainees to visualize injuries, fractures, or internal organ damage without invasive procedures, supporting both anatomical learning and forensic analysis.

CONCLUSION

In conclusion, we can summarize the fact that the blending of Virtual Reality (VR) and Augmented Reality (AR) in forensic training marks a significant leap forward in how we prepare forensic professionals for real-life investigations. These technologies not only create safer and more adaptable training environments but also boost the realism and repeatability of crime scene exercises. They give students and investigators the chance to make mistakes and learn from them without risking any evidence, which fosters a deeper understanding and skill enhancement.

In essence, VR and AR serve as powerful alternatives and complements to traditional crime scene training methods. Just because VR and AR makes it easier for use in Forensic training but they may not completely replace hands-on training, they do a fantastic job of minimizing logistical hurdles, cutting costs, and lowering risks, all while expanding access to a variety of intricate crime scene scenarios. Research consistently highlights VR and AR as vital tools for the future of forensic science education and practice.

FUTURE SCOPE

Virtual Reality and Augmented Reality technologies are slowly reshaping the image of forensic science, with valuable applications beyond educational learning. One of the hopeful advancements is their potential use in real crime scene investigations, where digital preservation of evidence would allow investigators to revisit the location virtually at will. Augmented Reality or Virtual Reality can be used in immersive reconstruction in courtroom presentation as it may help judges, lawyers, and jurors better understand complex forensic information by being there. With AI combined with these technologies, the result could be intelligent systems that identify and analyse evidence quicker or even anticipate crime scene patterns. As the developments continue, AR technology becomes smaller and less expensive, meaning that forensic analysts can potentially take light equipment with instant access to scene data into the field. The equipment can also enable better collaboration, with experts in remote locations being able to examine the same virtual scene at the same time. In forensic medicine, AR can allow pathologists to view internal trauma non-invasively, increasing the accuracy and efficiency of autopsies. Additionally, as VR and AR simulations become increasingly realistic and responsive, students in forensic training programs can gain hands-on experience in immersive crime scenes so that they can hone their analytical and decision-making skills in a safe, controlled environment.

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